RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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OF

THE GEOLOGICAL SURVEY OF INDIA,

VOLUME LXII.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part I] 1929. [April.

GENERAL REPORT FOR 1928. BY SIR EDWIN PASCOE, M.A., SC.D. (CANTAB.), D.SC. (LOND.), F.G.S., F.A.S.B., *Director, Geological Survey of India.*

DISPOSITION LIST.

DURING the period under report the officers of the Department were employed as follows:—

Superintendents.

DR. L. L. FERMOR . Remained at headquarters and acted as Palæontologist from the 13th January to the 2nd March 1928. Officiated as Director from the 5th March to the 8th December 1928. Placed in charge of the Central Provinces Party.

DR. G. E. PILGRIM . Granted combined leave for two years and twelve days with effect from the 13th January 1928.

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MR. G. H. TIPPER .	On combined leave.
DR. G. DE P. COTTER .	Returned from the field on the 2nd March 1928. Acted as Palæontologist from the 3rd March to the 3rd November 1928. Placed in charge of the North-West Party and left for the field on the 5th November 1928.
DR. J. COGGIN BROWN	Continued in charge of the Burma Party; also acted as Technical Adviser to the Tariff Board from the 20th April to the 19th May 1928.
MR. H. CECIL JONES .	Returned from leave on the 12th March 1928. Left for fieldwork in Bihar and Orissa on the 27th March and returned to headquarters on the 22nd April. Placed in charge of the Bihar and Orissa Party. Appointed Palæontologist with effect from the 4th November 1928.

Assistant Superintendents.

DR. A. M. HERON	Returned from the field on the 6th May 1928. Placed in charge of the Rajputana Party and left for the field on the 8th November 1928.
DR. C. S. FOX . .	Returned from the field on the 18th May 1928. While placed in charge of the Coal-fields Party, remained at headquarters to complete the memoir on the Coal-fields of India.

MR. H. CROOKSHANK .	Returned to headquarters from the field on the 6th May 1928. Attached to the Central Provinces Party and left for the field on the 8th November 1928.
MR. G. V. HOBSON	Returned from the field on the 10th May 1928. Attached to the Burma Party for the purpose of making a geological survey of the Northern Shan States. Left for Burma on the 14th October 1928.
MR. E. L. G. CLEGG .	Remained at headquarters in charge of Office.
RAO BAHADUR S. SETHU RAMA RAU.	Returned from the field on the 11th May 1928. Attached to the Coal-fields Party and proceeded to the field on the 27th November 1928.
RAO BAHADUR M. VINAYAK RAO.	Granted leave on average pay for six months and one day with effect from the 17th April 1928. Deputed to inspect the Siruvani and Metur Dam Sites. Returned from leave on the 17th October. Detailed for the continuance of the survey of the North Arcot, Chittoor and Salem districts in the Madras Presidency. Left for the field on the 3rd December 1928.
MR. E. J. BRADSHAW .	Attached to the Burma Party; remained in Burma throughout the period. Acted as Resident Geologist at Yenangyaung with effect from the 15th March 1928.
MR. A. L. COULSON .	Remained at headquarters as Curator of the Geological Museum and Laboratory.

MR D. N. WADIA .	Returned from the field on the 8th June 1928. Attached to the North-West Party and left for the field on the 30th October 1928.
DR. J. A. DUNN . .	Returned from the field on the 14th May 1928. Granted leave on average pay for twenty-nine days with effect from the 19th September. Attached to the Bihar and Orissa Party and resumed fieldwork on the 20th October 1928.
MR. C. T. BARBER .	Continued as Resident Geologist at Yenangyaung and Official Member of the Yenangyaung Advisory Board till the 14th March 1928. Granted combined leave for one year with effect from the 15th March 1928.
MR. E. R. GEE . .	Returned from field-work in the Salt Range of the Punjab on the 11th May 1928. Attached to the Coal-fields Party and left for the field on the 13th October 1928.
MR. W. D. WEST. .	Remained at headquarters till the 6th March 1928; left for the field on the 7th March to resume his work in the Punjab and United Provinces Himalaya. Returned from the field on the 7th July 1928. Granted combined leave for one year and one month with effect from the 10th August 1928.
MR. A. K. BANERJI .	Returned from the field on the 2nd May 1928. Granted combined leave for one year with effect from the 27th August 1928.

DR. M. S. KRISHNAN . Returned from the field on the 1st May 1928. Granted leave on average pay for one month with effect from the 18th May 1928. Returned from leave on the 18th June. Services placed at the disposal of the Department of Education, Health and Lands for a period of three months with effect from the 1st July 1928. Attached to the Bihar and Orissa Party; left for the field on the 19th November 1928.

MR. P. LEICESTER . Attached to the Burma Party; remained in Burma throughout the period under report.

DR. S. K. CHATTERJEE. On leave till the 4th March 1928. Resumed work in the Central Provinces on the 5th March. Returned from the field on the 28th April. Attached to the Central Provinces Party and left for the field on the 11th November 1928.

MR. J. B. AUDEN . Returned from the field on the 14th July 1928. Granted combined leave on average pay for seven months and twenty-six days with effect from the 19th November 1928.

MR. V. P. SONDHI . Returned to Rangoon from field-work in Burma on the 30th April 1928, and crossed to Calcutta for recess on the 15th May. Granted leave on average pay for one month and one day with effect from the 17th September. Returned from leave on the 30th October 1928. Attached to the Burma Party and left for Burma on the 4th November 1928.

MR. B. B. GUPTA .	Returned to Rangoon from field-work in Burma on the 5th May and crossed to Calcutta for recess on the 12th July 1928. Attached to the Burma Party and left for Burma on the 4th November 1928.
DR. H. L. CHHIBBER .	Appointed Assistant Superintendent, Geological Survey of India; joined the Department on the 4th January 1928. Attached to the Burma Party and left for Burma on the 13th January 1928. Returned to Rangoon on the 7th May 1928 and crossed to Calcutta for recess on the 18th September 1928. Again attached to the Burma Party and left for Burma on the 9th November 1928.

Chemist.

DR. W. A. K. CHRISTIE	At headquarters till the 14th June 1928. Granted combined leave for five months and eight days with effect from the 15th June 1928. Returned from leave and resumed charge of his duties on the 26th November 1928. Remained at headquarters during the rest of the period.

Artist.

MR. K. F. WATKINSON	At headquarters till the 1st April 1928. Granted leave on average pay for 8 months with effect from the 2nd April 1928. Returned from leave and resumed charge of his duties from the 1st December 1928.

Sub-Assistants.

MR. D. S. BHATTACHARJI	Returned to headquarters from field-work in the Central Provinces on the 7th February 1928. Granted leave on average pay for two months and fifteen days with effect from the 16th February 1928. Returned from leave on the 1st May 1928. Attached to the Central Provinces Party and left for the field on the 7th November 1928.
MR. B. C. GUPTA .	Returned from the field on the 14th May 1928. Attached to the Rajputana Party and left for the field on the 8th November 1928.
MR. H. M. LAHIRI .	Returned from the field on the 14th May 1928. Attached to the North-West Party; left for the field on the 11th November 1928.
MR. L. A. NARAYANA IYER.	On combined leave.
MR. P. N. MUKERJEE.	At headquarters.
MR. A. K. DEY . .	Appointed Sub-Assistant, Geological Survey of India, with effect from the 14th March 1928. Returned from the field on the 19th April 1928. Attached to the Bihar and Orissa Party and left for the field on the 5th November 1928. Granted leave on average pay for thirteen days with effect from the 10th December 1928.

Assistant Curator.

MR. P. C. ROY . . At headquarters till the 23rd April 1928. Granted leave on average pay for three months with effect from the 24th April 1928. Returned from leave on the 24th July 1928 and remained at headquarters during the rest of the period.

Field Collectors.

N. K. N. AIYENGAR . Remained at headquarters till the 30th September 1928. Granted leave on average pay for seventeen days with effect from the 1st October 1928. Returned from leave on the 30th October 1928 and remained at headquarters during the rest of the period.

A. K. DEY . . . Detailed for the collection of specimens in Bombay. Promoted to the grade of Sub-Assistant with effect from the 14th March 1928.

AUSTIN M. N. GHOSH Appointed Field Collector, Geological Survey of India, with effect from the 14th March 1928. Remained at headquarters till the 31st August 1928. Granted combined leave out of India for two years with effect from the 1st September 1928.

Museum Assistants.

AUSTIN M. N. GHOSH . At headquarters. Promoted to the post of Field Collector with effect from the 14th March 1928.

D. GUPTA . . . At headquarters.

The cadre of the Department continued to be 6 Superintendents, 22 Assistant Superintendents and one Chemist. There was one vacancy in the grade of Assistant Superintendent and this was filled up during the year under report.

ADMINISTRATIVE CHANGES.

Promotions and Appointments.

Dr. L. L. Fermor was appointed to officiate as Director with effect from the 5th March *vice* Sir Edwin Pascoe, Director, on leave, and reverted to his substantive appointment as Superintendent on the 9th December 1928 on the return of the latter.

Dr. A. M. Heron continued to officiate as Superintendent *vice* Mr. G. H. Tipper on leave.

Dr. C. S. Fox officiated as Superintendent up to 11th March 1928 *vice* Mr. H. C. Jones on leave; and again from the 12th March 1928 onwards *vice* Dr. G. E. Pilgrim on leave.

Mr. E. L. G. Clegg was appointed to officiate as Superintendent from the 13th January 1928 up to the 11th March 1928 *vice* Dr. G. E. Pilgrim on leave, and again from the 12th March 1928 to the 8th December 1928 *vice* Dr. L. L. Fermor officiating as Director.

Mr. A. L. Coulson continued to act as Curator, Geological Museum and Laboratory.

Dr. G. E. Pilgrim acted as Palæontologist till the 12th January 1928 when he was relieved by Dr. L. L. Fermor. From the 3rd March 1928 till the 3rd November 1928 Dr. G. de P. Cotter acted as Palæontologist and thereafter Mr. H. C. Jones.

Mr. J. B. Auden and Mr. Ved Pall Sondhi have been confirmed in their appointments as Assistant Superintendents.

Dr. H. L. Chhibber, D.Sc. (Punjab), F.G.S., F.R.G.S., was appointed an Assistant Superintendent with effect from the 4th January 1928.

Mr. A. K. Dey, Field Collector, was promoted to the grade of Sub-Assistant with effect from the 14th March 1928.

Mr. Austin M. N. Ghosh, Museum Assistant, was promoted to the post of Field Collector with effect from the 14th March 1928.

Leave.

Sir Edwin Pascoe was granted combined leave out of India for 9 months and 10 days with effect from the 5th March 1928.

Dr. G. E. Pilgrim was granted combined leave out of India for two years and twelve days with effect from the 13th January 1928.

Rao Bahadur M. Vinayak Rao was granted leave on average pay for six months and one day with effect from the 17th April 1928.

Dr. J. A. Dunn was granted leave on average pay for twenty-nine days with effect from the 19th September 1928.

Mr. C. T. Barber was granted combined leave out of India for one year with effect from the 15th March 1928.

Mr. W. D. West was granted combined leave out of India for one year and one month with effect from the 10th August 1928.

Mr. A. K. Banerji was granted combined leave out of India for one year with effect from the 27th August 1928.

Dr. M. S. Krishnan was granted leave on average pay for one month with effect from the 18th May 1928.

Mr. J. B. Auden was granted combined leave out of India for seven months and twenty-six days with effect from the 19th November 1928.

Mr. V. P. Sondhi was granted leave on average pay for one month and one day with effect from the 17th September 1928.

Dr. W. A. K. Christie was granted combined leave out of India for five months and eight days with effect from the 15th June 1928.

Mr. K. F. Watkinson was granted leave out of India on average pay on medical certificate for eight months with effect from the 2nd April 1928.

Mr. D. S. Bhattacharji was granted leave on average pay for two months and fifteen days with effect from the 16th February 1928.

Mr. A. K. Dey was granted leave on average pay for thirteen days with effect from the 10th December 1928.

LECTURESHIP.

Mr. A. L. Coulson continued as Lecturer on Geology at the Presidency College, Calcutta, throughout the year.

Dr. M. S. Krishnan acted as a whole-time Lecturer on Geology at the Forest College, Dehra Dun, for a period of three months from the 1st July 1928.

POPULAR LECTURES.

A popular lecture on "The Geological History of a River System" was delivered in the Indian Museum by Mr. E. L. G. Clegg during the year.

LIBRARY.

The additions to the Library amounted to 4,115 volumes, of which 1,115 were acquired by purchase and 3,000 by presentation and exchange.

PUBLICATIONS.

The following publications were issued during the year under report:—

1. Records, Geological Survey of India, Vol. LX, part 4.
2. Records, Geological Survey of India, Vol. LXI, part 1.
3. Records, Geological Survey of India, Vol. LXI, part 2.
4. Records, Geological Survey of India, Vol. LXI, part 3.
5. Memoirs, Geological Survey of India, Vol. XLIX, part 2.
6. Memoirs, Geological Survey of India, Vol. L, part 2.
7. Memoirs, Geological Survey of India, Vol. LI, part 2.
8. Palæontologia Indica, New Series, Vol. IX, Memoir No. 2, Part II.
9. Palæontologia Indica, New Series, Vol. IX, Memoir No. 2, Part III.
10. Palæontologia Indica, New Series, Vol. X, Memoir No. 3, Fasc. I.
11. Palæontologia Indica, New Series, Vol. X, Memoir No. 4.
12. Palæontologia Indica, New Series, Vol. XI, Part 1.
13. Palæontologia Indica, New Series, Vol. XII.
14. Palæontologia Indica, New Series, Vol. XIII.

MUSEUM AND LABORATORY.

Staff.

Mr. A. L. Coulson continued to fill, with his usual ability and zeal, the post of Curator of the Geological Museum and Laboratory for the year under report. Babu Purna Chandra Roy remained Assistant Curator except for the period of his absence on leave from the 24th April to the 23rd July; during this period, Babu N. K. N. Aiyengar performed the duties of Assistant Curator in addition to his own duties as Field Collector. Babu Austin Manindra Nath Ghosh continued as Museum Assistant until the 13th March when he was promoted to the grade of Field Collector; Babu Dasrathi Gupta remained as Museum Assistant throughout the year being assisted after Babu Austin Manindra Nath Ghosh's promotion by two temporary Museum Assistants, Babus Bhabesh Chandra Roy and Amiya Kumar Ghosh.

Babu Mahadeo Ram continued to act as Laboratory Attendant throughout the year except for the period of his absence on leave from the 21st February to the 18th April. Babu Lekh Raj conti-

nued to act as Chemical Assistant to the Burma Party, Rangoon, until the 27th April, since when he has undergone training in the Laboratory of the Department in Calcutta.

Chemist.

Before his departure on combined leave on the 15th June, and after his return to Calcutta on the 26th November, Dr. W. A. K. Christie continued his duties as Chemist, remaining at headquarters for this period.

Determinative Work and Analyses.

The number of specimens referred to the Curator for examination and report was 722; this figure includes 150 beads from Mohenjo Daro, Sind, mentioned in the last General Report[1] and 140 specimens of which assays, analyses and other special determinative work were carried out. The corresponding figures for 1927 were 676 and 46 respectively. Chemical work included analyses of gahnite by Dr. W. A. K. Christie,[2] of allophane by Babus P. C. Roy and Mahadeo Ram, of sillimanite-rocks, limestones, coal, hæmatite, etc., and assays for gold and silver. An important series of analyses of vitrains and coals was performed in the Laboratory for Drs. L. L. Fermor and C. S. Fox in connexion with the study of the properties of coal and the resurvey of the coal-fields of India.

Allophane.

An occurrence of allophane has been noted at Tikak, Assam. A note on the occurrence of this mineral is being published in the Records.[3]

Donations to Museums, etc.

During the year under review, collections of minerals and rocks were made to the undermentioned institutions:—

1. The Commercial Museum, Calcutta University.
2. The Central Museum, Nagpur.
3. The Museum, Udaipur, Rajputana.
4. The Indian School of Mines, Dhanbad, Bihar and Orissa.
5. The Osmania Central Technical Institute, Hyderabad (Deccan).
6. The Islamia College, Calcutta.
7. The David Hare Training College, Calcutta.
8. The Gokhale Memorial Girls' School, Calcutta.
9. Visva Bharati, Bolepur, Bengal.
10. Birla Vidapith, Pilani, Jaipur, Rajputana.
11. The Board High School, Uttiramerur, Madras Presidency.

[1] *Rec. Geol. Surv. Ind.*, LXI, pp. 11-12. 1928.
[2] *Rec. Geol. Surv. Ind.*, LXI, p. 316, 1928.
[3] *Rec. Geol. Surv. Ind.*, LXI, pp. 364-365, 1929.

In addition, the following specific donations were made:—

1. A fragment of the Jajh deh Kot Lalu meteorite (Stone—No. 291) to the British Museum.
2. A fragment of the Lua meteorite (Stone—No. 292) to the British Museum.
3. Juddite to the United States National Museum, Washington, U. S. A.
4. Magnesioblythite-rock with beldongrite, and spandite-rock to the United States National Museum, Washington, U. S. A.
5. Jadeite and associated rocks to Prof. A. Lacroix, Muséum National d'Histoire Naturelle, Paris.
6. Samples of manganese ores to H. Bertram Bateman, Esq., London.
7. Beryl crystals to Sir P. C. Roy, University College of Science, Calcutta.

Additions to Collections.

In addition to a large number of specimens collected by officers of the Department, the following important Indian specimens were received and incorporated in the collections of the Geological Survey of India:—

1. Stone meteorite from Lua, Udaipur State, Rajputana—Mewar Durbar, Udaipur (by exchange).
2. Stone meteorite from Naoki, Parbhani district, H. E. H. the Nizam's Dominions—Mr. G. H. H. Mills.
3. Leucopyrite; Kodarma, Hazaribagh district—Messrs. F. F. Chrestien and Co.
4. Löllingite; Kodarma, Hazaribagh district—Mr. F. G. Percival.
5. Löllingite; Kodarma, Hazaribagh district—Mr. C. D. Chatterjee.
6. Uranium ore.—F. O. Lechmere-Oertel.
7. Pyromorphite in lead ore; Central Provinces.—Messrs. R. V. Briggs and Co.
8. Dressed asbestos; Rajupalem, Kamalapuram *taluk*, Cuddapah district, Madras Presidency.—Director of Industries, Madras.
9. Corundum with hornblende; Madras Presidency.—Director of Industries, Madras.
10. Pyrrhotitic ore; Polur, North Arcot, Madras Presidency.—Mr. H. A, Golwynne.

The following foreign specimens were added to the collections of the Department :—

1. Two fragments of the Béréba meteorite; French West Africa —Prof. A. Lacroix (by exchange).
2. Crystals of albite and adularia, with muscovite; Switzerland. —Dr. R. L. Walker (by exchange).
3. A rare variety of hæmatite, with adularia; Switzerland.— Dr. R. L. Walker (by exchange).
4. Sphene and adularia; Switzerland.—Dr. R. L. Walker (by exchange).
5. Fibres of amianthus, with smoky quartz; Switzerland.—Dr. R. L. Walker (by exchange).
6. Anatase and adularia, with traces of hæmatite, in a sedimentary gneiss; Switzerland.—Dr. R. L. Walker (by exchange).
7. Crushed aggregate of desmine; Switzerland.—Dr. R. L. Walker (by exchange).
8. Smoky quartz; Switzerland.—Dr. R. L. Walker (by exchange).
9. Thorotungstite; Kinta, Federated Malay States.—Director, Geological Survey, Federated Malay States.
10. Monazite; Kinta, Federated Malay States.—Director, Geological Survey, Federated Malay States.
11. Tin ore in limestone, Beatrice Mine, Federated Malay States. —Director, Geological Survey, Federated Malay States.
12. An ornament of Roumanian rock-salt.—Rai Saheb Gyanendra Nath Dey (through Mr. G. S. Hardy).
13. Spurrite; Mexico.—United States National Museum (by exchange).
14. Hillebrandite; Mexico.—United States National Museum, Washington (by exchange).
15. Mangan-diaspore; South Africa.—Through Dr. W. A. K. Christie.
16. Blue ground; South Africa.—Director, Geological Survey of South Africa (by exchange).
17. Eclogite boulders; South Africa.—Director, Geological Survey of South Africa (by exchange).
18. Malachite; Tibet.—Col. F. M. Bailey.
19. Azurite; Tibet.—Col. F. M. Bailey.
20. Orpiment; Tibet.—Col. F. M. Bailey.
21. Realgar; Tibet.—Col. F. M. Bailey.

22. Magnesite ; Tibet.—Col. F. M. Bailey.
23. Kaolin, Tibet.—Col. F. M. Bailey.
24. Specimens of "Tekka clays," Triassic quartzites, and rocks of the "Raub" series; Federated Malay States.—Director, Geological Survey, Federated Malay States.

The Department is specially indebted to Mr. H. M. Page, late Professor of Geology in the College of Engineering, Poona, for the presentation of a fine collection of typical foreign rocks, a reference set of fossils and several cabinets of minerals. The rocks have been sectioned and now form a valuable reference set.

Meteorites.

The large stone meteorite weighing 8,632 grammes, which fell at Lua, Udaipur State, on the 26th June 1926, and which was lent to this Department,[1] has since been very kindly presented to the Geological Survey of India by the Mewar Durbar in exchange for a cast of the specimen and a collection of Indian minerals. It now forms a valuable addition to the collections and has been registered as Stone—No. 292 E.

Two pieces of the stone meteorite which fell at Béréba, Haute Volta, French West Africa, on the 27th June 1924, and which weighed 5·8118 and 3·8384 grammes, were presented to this Department by Prof. A. Lacroix of the Muséum National d'Histoire Naturelle, Paris, in exchange for fragments of the Nageria and Lakangaon meteorites; the Béréba specimens have been registered as Stone—Nos. 293 A. and B.

In the "Statesman", Calcutta, of the 20th September 1928, the reputed fall of a large meteorite "near the village of Kanth, in the district of Jalaun, United Provinces," was published; this report on investigation was proved to be incorrect.

Four stones of a meteoric shower are reported to have fallen about 5 P.M. on the 29th September 1928, at the villages of Naoki (19° 14′ 30″: 77° 0′ 0″), Malegaon and Kawargaon near Purna in the Parbhani district of H. E. H. the Nizam's Dominions, Hyderabad (Deccan). Of these, a fine stone meteorite which fell at Naoki was presented to this Department by Mr. G. H. H. Mills, Criminal Investigation Department, H. E. H. the Nizam's Government; this weighed 4920·7 grammes when received by this Department and has been registered as Stone—No. 294. Efforts are being made to

[1] *Rec. Geol. Surv. Ind.*, LX, p. 13; *ibid.*, LXI, p. 14; *ibid.*, pp. 318-24.

recover the other stones of this shower. A description of the Naoki stone and such others as are recovered will be published shortly.

Burma Laboratory.

Owing to the deputation of the Chemical Assistant to Calcutta for training, the number of specimens examined underwent a marked diminution. Some 88 mineral specimens were added to the collection during 1928 in the Burma Laboratory.

Among the donations received for the Museum, the magnificient specimens of wolfram in quartz, presented to the Department by the Bombay Burma Trading Co., Ltd., deserve especial mention. The choicest of these has been sent for display in the Imperial collection in Calcutta.

Assay furnaces have been installed in the Rangoon Office, a new chemical balance has been purchased, and it is anticipated that there will be a considerable advance in this branch of the office work in the near future.

DRAWING OFFICE.

The Artist, Mr. K. F. Watkinson after holding charge for four months, proceeded on leave for eight months, during which period Rai Sahib Kali Dhan Chandra officiated.

Publications.

The total number of printed impressions made was 57,050 including impressions of 33 plates for the Records, 37 plates for the Memoirs and 7 plates for the Palæontologia Indica. This number approximates closely to that of last year.

Geological maps.

The drawing work in connection with the new geological map of India on a scale of 1 inch=32 miles, has been finished and sent to the Survey of India for reproduction. The colour printing will require such a large number of separate plates that this map is not expected to be ready for publication till 1930.

The survey of the Ranigunge coal-field is now complete, and several of the 25 sheets on a scale of four inches to a mile have been prepared for reproduction.

The reproduction of the 1-inch map of Singhbhum in eight sheets has now been completed and sent to the Survey of India for colour printing.

Some 2,090 map sheets were received during the year while 41 original geologically coloured maps have been handed in.

Photographic section.

The photographic section has been fully occupied with the preparation of prints to illustrate officers' reports, etc. Some 344 negatives in various sizes have been registered while 4,900 prints have been made.

PALAEONTOLOGY.

Dr. G. E. Pilgrim continued to fill the post of Palæontologist up to the 12th January 1928. Dr. L. L. Fermor took charge from the 13th January until the 2nd March, Dr. G. de P. Cotter from the 3rd March till the 3rd November and Mr. H. C. Jones from the 4th November till the end of the year. Sub-Assistant P. N. Mukerjee assisted the Palæontologist with routine Museum work and with the determination of specimens during the year. Field Collector A. M. Ghosh continued the cataloguing and preparation of the card index of the specimens in the Fossil Vertebrate gallery; he also commenced the cleaning and replacing of labels in the Klipstein collection. The card index of the invertebrate collection has been kept up to date.

During 1928 the following memoirs have been published in the *Palæontologia Indica*:—

(1) L. F. Spath: "Revision of the Jurassic Cephalopod Fauna of Kachh." Parts II and III of Memoir No. 2, Vol. IX of the New Series.

(2) H. Douvillé: "Les Couches à Cardita Beaumonti dans le Bélouchistan" Fasc. I of Memoir No. 3, Vol. X of the New Series.

(3) E. W. Vredenburg: "A Supplement to the Mollusca of the Ranikot Series edited with notes by G. de P. Cotter." Memoir No. 4, Vol. X of the New Series.

(4) B. Sahni: "Revisions of Indian Fossil Plants; Coniferales." Part I, Vol. XI of the New Series

(5) H. S. Bion: "The Fauna of the Agglomeratic Slate Series of Kashmir, with an Introductory Chapter by C. S. Middlemiss." Vol. XII of the New Series.

(6) G. E. Pilgrim: "The Artiodactyla of the Eocene of Burma." Vol. XIII of the New Series.

The following paper of palæontological interest has appeared in the Memoirs :—

(1) E. Vredenburg: "Descriptions of Mollusca from the Post-Eocene Tertiary Formation of North-Western India: Gastropoda (in part) and Lamellibranchiata." (Vol. L, pt. 2).

The following papers of palæontological interest have appeared in the Records :—

(1) "A Permo-Carboniferous Marine Fauna from the Umaria Coal-field," by F. R. Cowper Reed: (Vol. LX, pt. 4).
(2) "Actinodon risinensis, n. sp. in the Lower Gondwanas of Vihi District, Kashmir," by D. N. Wadia and W. E. Swinton. (Vol. LXI, pt. 1).
(3) "The Lower Canine of an Indian Species of Conohyus," by G. E. Pilgrim and N. K. N. Aiyengar (Vol. LXI, pt. 2).
(4) "The Cretaceous Dinosaurs of the Trichinopoly District and the Rocks associated with them," by C. A. Matley. (Vol. LXI, pt. 4).
(5) "Some Orbitolinæ from Tibet," by G. de P. Cotter. (Vol. LXI, pt. 4).

The following papers of palæontological interest are in the Press, and are expected to be published in 1929.

Memoirs in the *Palæontologia Indica* :—

(1) H. Douvillé: "Les Couches à Cardita Beaumonti dans le Sind." Fasc. II of Memoir No. 3, Vol. X of the New Series.
(2) Lt.-Col. L. M. Davies, Ethel D. Currie, Helen M. Muir-Wood, L. R. Cox, L. F. Spath and J. W. Gregory: "The Fossil Fauna of the Samana Range." Parts I to VIII of Vol. XV of the New Series.
(3) F. R. Cowper Reed: "Upper Carboniferous Fossils from Tibet."

Paper of palæontological interest in the *Records* :—

(1) F. R. Cowper Reed: "New Devonian Fossils from Burma."

In the early part of the year, Dr. G. de P. Cotter and Sub-Assistant H. M. Lahiri were deputed to assist Dr. F. R. Cowper Reed in making a collection of fossils and in examining the Permo-Carboniferous sections in the neighbourhood of Warcha Mandi in

the Salt Range. The results are incorporated in a joint paper by Dr. Reed, Dr. Cotter and Mr. Lahiri to be published later. The discovery of three species of *Gangamopteris* in a bed which is interstratified in the lower part of the Productus Limestone is important. *Gangamopteris* beds have been recorded previously in Kashmir where the stratigraphical position of the beds has been placed at the base of the Permian by Mr. C. S. Middlemiss and Dr. C. Diener. The beds now discovered in the Salt Range appear to correspond exactly in age with the beds in Kashmir. The topmost 100 feet of the Productus Limestone are full of cephalopods, amongst which have been identified *Pseudosageceras*, *Meekoceras*, *Aspidites*, *Flemingites* and *Ophiceras*, indicating a Lower Triassic age.

Dr. L. F. Spath continued his revision of the Cephalopod fauna of Kachh, and Parts II and III of Memoir 2, Volume IX of the *Palæontologia Indica* were published during the year. The manuscript of Part IV is expected shortly.

Dr. Baini Prashad of the Zoological Survey of India has continued his work on the revision of the fossil *Unionidæ* and the *Viviparidæ* in the Geological Survey collections.

Our collection of Indian Proboscidia, one of the finest in the world, embraces a regular succession of forms extending almost without interruption from the Lower Miocene to the Pleistocene. As the collection is in serious need of revision, determination and description, not only from the zoological, but also from the stratigraphical point of view, the services of Mr. A. T. Hopwood of the British Museum, a specialist in the Proboscidia, were accepted for the Cold Weather of 1928-1929, in order to study the Proboscidia in Calcutta. Mr. Hopwood is now engaged on the examination of the specimens, and at its conclusion will prepare a memoir on his work.

Dr. Cotter examined a number of specimens of *Orbitolinæ*, collected by the late Sir Henry Hayden from north of Lhassa in Tibet, and his results are given in a paper which is now in the press and will shortly appear in the *Records*. Dr. Cotter records that the collection contains apparently a single species, represented by both megalospheric and microspheric forms. This species of *Orbitolina* differs, so far as was ascertained, from any previously described species; he has, therefore, given it the new specific name of *O. tibetica*.

Some specimens sent for identification by Mr. E. T. Vachell of the Burmah Oil Company from Fort Munro, Punjab, were examined

by Dr. Cotter who found that, although not sufficiently well-preserved for accurate determination, they indicated an Upper Cretaceous age. Amongst the specimens was an oyster probably identical with *Exogyra overwegi* Buch from the Overwegi beds of Egypt. Amongst specimens of *Orbitoides* from the Nishpa Shales, were *Orbitoides* (*s. str.*) spp. cf. *O. apiculata* Schlumb. and *O. socialis* Leymerie. Among the mollusca was found a form probably identical with Hislop's *Cerithium leithi*; the generic position is doubtful since the mouth is not preserved. Another species, represented by four specimens, is probably a *Semisolarium* of the group of *S. monilifere* from the Gault and *S. karapaudense* Stol. from the Ariyalur of southern India. In addition, there were specimens of *Natica* (or perhaps *Crommium*), a badly preserved *Pyrgulifera* cf. *P. striata* (Douvillé), and two specimens of an indeterminable *Cardium* resembling in shape *C. harnaiense* Noetl. but smaller and with less numerous ribs.

A description of a collection of fossils made by Colonel L. M. Davies in the Samana Range on the North-West Frontier is now in the Press and will form Parts I to VIII of Vol. XV of the New Series. In his description in Part VI Colonel Davies states that foraminifera have not been detected in the first nine beds of the Samana series, but they appear suddenly, in great numbers, near the base of bed (10), and are to be found at all succeeding levels of the series. *Rotalidæ* appear from the first, being represented by several species of the remarkable genus *Dictyoconoides.* At the top of bed (10) the foraminiferal fauna changes considerably. The *Dictyoconoides* and most of their small associates disappear abruptly, and are replaced by nummulites, operculines, and occasional discocyclines in bed (11). Molluscs and echinoid fragments are found in some layers of bed (11). With the advent of bed (12) the fauna changes again. The molluscs and most of the large foraminifera of bed (11) disappear, while smaller foraminifera of the general types common to bed (10) again become abundant. The discovery in bed (10) (the Lockhart Limestone), of all the three well-marked species of *Dictyoconoides* which are found in the uppermost Ranikot beds of Thal and Sind lends support to the view that bed (10) of the Samana series belongs to the Ranikot formation. The fact, however, that *D. conditi* has only been found in the uppermost layers of bed (10), would seem to indicate that the bed, as a whole, is earlier than the uppermost Ranikot. This is supported by the fact that a very

reduced representative of Samana bed (10) has been found by Colonel Davies at Thal, where it underlies the entire Upper Ranikot and part of the Lower Ranikot as well. This last fact seems to show that the lower part at least of bed (10) dates from the Lower Ranikot; from this it would appear that the Hangu Shale, or Samana bed (9), belongs to the Lower Ranikot.

Professor J. W. Gregory has described in Part VII of the above-mentioned volume the Corals which were collected by Colonel Davies. The main part of the collection was made at Thal in the North-West Province, and the fauna represents that of the Ranikot series of Sind. Some corals from Samana bed (9) have been compared with the material obtained from Thal. The Brachiopods collected in the Samana Range have been described by Miss H. M. Muir-Wood in Part III. She states that they are associated with undoubted Gault Ammonites—such as *Douvilleiceras mammillatum* (Schloth)—which establish the age of the fauna. Some specimens, collected from the lowest fossiliferous bed found on the Samana Range, have been referred to the species *Rhynchonelloidea arcuata* (Quenstedt) and the beds are therefore assumed to be of Upper Bathonian or Lower Callovian age. This Jurassic species is of considerable importance, as it is the only fossil collected from these lower beds; *R. arcuata* has not been previously recorded from India. Dr. Ethel D. Currie has described in Part II, the Echinoids collected from the Samana Range. The collection which comprises four species are very poorly preserved but from the evidence of associated specimens of *Douvilleiceras mammillatum*, an Albian age may, without inconsistency, be assigned to the Echinoids. Mr. L. R. Cox has examined and described in Part VIII the Molluscan fauna from bed (9), the Hangu Shales, and he finds that, while a few species are identifiable with Upper Ranikot types, these appear to be types with a considerable vertical range, and the great majority of the species are new. It seems difficult, therefore, to identify the bed with any known Upper Ranikot horizon, and it is perhaps best to refer it to the Lower Ranikot; it could hardly be older, since the fauna has no affinity with that of the *Cardita beaumonti* beds. Dr. L. F. Spath has examined and described in Part V, the Ammonoidea and Mr. L. R. Cox in Part IV the Gastropoda and Lamellibranchiata collected from the uppermost few feet of the Main Sandstone series, bed (4). The ammonites in this bed fix its age as Albian, but they indicate that this bed of a few feet in

thickness is a reduced representative of several zones. The principal fossil is *Douvilleiceras mammillatum* (Schlotheim). Dr. Spath finds that the Gault faunas of Samana and Hazara are on the whole of Middle Albian age.

Mr. E. A. Smythies, Deputy Conservator of Forests, submitted for identification a piece of rock found on the line of the great fault which divides the lower Siwalik (Nahan) sandstone from the Himalayan Purana rocks at an altitude of about 2,800 feet near the Mundal river, Garhwal district, United Provinces. The fossils examined were very indistinct and imperfect, and all that could be detected under the microscope were some doubtful sections of calcareous algæ, probably referable to *Lithothamnion*, and some sections of corals and gastropods.

Mr. J. H. Smith of Bhuj (Kachh) forwarded for identification some specimens of corals found on a hill 200 feet high, about 6 miles inland from the sea near Karachi. Dr. Cotter identified them as *Brachyphyllia indica* Duncan, a characteristic Gaj species.

Mr. J. G. Cunningham of the Bengal Coal Company submitted for examination a specimen of a fossil plant from a bed containing numerous ironstone nodules embedded in a sandstone matrix, forty feet above the "Queen" coal-seam worked at Silimpopon, British N. Borneo. The specimen is dicotyledonous and, according to Dr. Cotter, probably identical with *Phyllites* (*Artocarpus*) *verbeekianus*. The leaves resembled those of *Artocarpus lakoocha*, a common living tree of Burma and Malaya. Dr. Cotter considers the specimen to be of Middle Eocene age, but agrees that the identification of trees by leaves alone must be regarded with the greatest caution.

The Assistant Director of Agriculture, Cuttack, forwarded to this department fossils obtained at a depth of 170 feet from the ground level whilst boring a well at Balasore. These specimens were embedded in a bed of gravel with some black clay. Dr. Cotter recognised some shark's teeth (*Carcharias*), probably identical with the living *C. acutidens*. Judging from the depth of the well the horizon might be in the "older alluvium" and therefore possibly of Pleistocene age.

Reference was made in the last General Report to a collection of fossils from Kanchanpur, Assam. This collection was enriched afterwards by the despatch of two boxes of material by Mr. H. M. Sale of the Burmah Oil Company in May 1928. Owing to Museum routine work the examination of the material could not be taken

up until the latter part of November. Besides the two species of *Isocardia* (*Meiocardia*) already mentioned in the above-mentioned report, the following were identified by Sub-Assistant P. N. Mukerjee :—

1. ? *Nucula alcocki Noetl.*
2. *Drillia* (*Crassispira*) cf. *dalabeensis* Vred.
3. *Drillia* cf. *protointerrupta Noetl.*
4. *Mactra protoreevesi Noetl.*
5. *Leda virgo* Mart.
6. *Balanus* (*Chirona*) cf. *birmanicus* Withers.
7. *Pyrula dussumieri* Valenc.
8. *Flabellum distinctum* Noetl.
9. *Dendrophyllia* sp.
10. *Cidaris* sp.
11. *Hipponyx* sp.

A considerable portion of the material is still, unavoidably, lying unworked and it is possible that a considerable number of species may be identified when the whole material is examined. The discovery is of exceptional interest owing to the scarcity of fossils in the Tertiary of Assam and to the difficulties of geological investigation in that densely forested region. In the last General Report the specific determination of one species of *Isocardia* (*Meiocardia*) *metavulgaris* Noetl. gave slender evidence for the assignation to the Kanchanpur fossil bed of an age equivalent to Mr. Vredenburg's Singu stage of Burma, corresponding to the Upper Nari of N. W. India and the Chattian of Europe (Upper Oligocene). The recognition, however, of the additional species mentioned above from the further material recently received from Mr. Sale shews that the Kanchanpur bed is younger and is to be referred to the Miocene (Gaj). The assemblage bears considerable resemblance to Noetling's fauna of the Miocene beds of Burma as well as to Martin's fauna from the Miocene of Java. The occurrence of the species *Drillu* (*Crassispira*) cf. *dalabeensis* Vred. from the Tertiary of Assam is interesting in view of the fact that *dalabeensis*, up to the present, is restricted to the Miocene of Burma (Dalabe) and has not been found in the Miocene of any other part of the Indian Empire. This species closely resembles *Drillia harpularia* Desmoulins from the Miocene of Australia, but the latter is less elongate and has decidedly broader spire whorls. *D. terebra* Basterot and *D. fratercula* Bellardi, from

the Miocene of Europe, also resemble the Assamese fossil. The Assamese species is characterised by ribs which are confluent from one whorl to another; it might well be regarded as a variety of *Drillia* (*Crassispira*) cf. *dalabeensis* Vred. The presence of the latter and other forms mentioned in the list above, shows that tha age of the Kanchanpur fossil bed is not Upper Oligocene but more likely Miocene (Gaj); this it is hoped to confirm when the results of the examination of the whole material are known.

Sub-Assistant P. N. Mukerjee was deputed in March 1924 to collect fossils from two new fossil localities discovered by Mr. E. S. Pinfold of the Indo-Burma Petroleum Company, (see *Rec., Geol. Surv. Ind.*, Vol. L, page 126) at Bagmara and Dalu in the Garo Hills, Assam. The specimens collected included a number of species new to Assam Tertiary geology. The specimens collected by Mr. Pinfold were examined by the late Mr. E. Vredenburg and his results were published in Vol. LI, Part 3 of these Records. Mr. Mukerjee's collection from Bagmara and Dalu contained not only almost all the species identified by Mr. Vredenburg, but also several additional forms.

The species, identified by Mr. Mukerjee, have been very kindly checked and corrected by Mr. F. E. Eames, Palæontologist to the Burmah Oil Company; they are as follow:—

1. *Solarium* (*Architectonica*) *nitens* Noetl.
2. *Sigaretus neritoides* Linné.
*3. *Turritella angulata* d'Orb.
*4. *Turritella pinfoldi* Vred.
5. *Conus ineditus* Michelotti.
6. *Conus odengensis* Martin var. *avaensis* Noetl.
7. *Conus odengensis* Martin.
8. *Conus vimineus* Reeve.
*9. *Siphonalia subspadicea* Vred.
10. *Calyptræa rugosa* Noetl.
11. *Clavatula birmanica* Vred.
*12. *Surcula promensis* Vred.
*13. *Drillia tjemoroensis* Martin (probably the variety described by Vredenburg from Burma).
14. *Pyrula condita* Brongn.
15. *Ranella nobilis* Reeve.
16. *Oliva australis* Duclos. var. *indica* Vred.

17. *Olivancillaria* (*Agaronia*) *nebulosa* Lamk. var. *pupa* J. de C. Sow.
*18. *Mitra chinensis* Gray var. *subscrobiculata* d'Orb.
19. *Terebra protoduplicata* Noetl.
20. *Terebra myaunguensis* Vred.
21. *Terebra reticulata* J. de C. Sow.
*22. *Terebra protomyuros* Noetl.
23. *Cryptospira birmanica* Vred.
24. *Clavilithes seminudus* Noetl.
25. *Latrunculus* (*Eburna*) *lutosa* Lam.
26. *Pleurotoma congener* Smith var. *mekranica* Vred.
27. *Rostellaria* sp.
28. *Hipponyx* sp.
29. *Dentalium junghuhni* Martin.
30. *Parallelipipedum prototortuosum* Noetl.
31. *Arca clathrata* Reeve var. *birmanica* Vred.
32. *Barbatia bataviana* Martin.
33. *Lucina pagana* Noetl.
34. *Dione protophilippinarum* Noetl.
35. *Tapes* (*Callistotapes*) *protolirata* Noetl.
36. *Cardium minbuense* Noetl.
37. *Ostræa papyracea* Noetl.
38. *Corbula socialis* Martin.
39. *Pinna vexillum* Born.
40. *Tellina protostriatula* Noetl.
41. *Tellina grimesi* Noetl.
42. *Mactra protoreevesi* Noetl.
43. *Leda ? virgo* Martin.
44. *Callianassa* cf. *birmanica* Noetl.
45. *Solen* sp.

Of the nine species identified from the specimens collected by Mr. Pinfold, seven have been recognized in this new collection and have been marked in the above list with a star. The rest are new to the Tertiary of Assam. On the evidence of the nine species Mr. Vredenburg concluded that the uppermost zones of the Tertiary beds in the Garo Hills are of an age equivalent to that of the Upper Gaj or Pyalo. This conclusion is corroborated by the large number of additional species characteristic of Upper Gaj identified by Mr. Mukerjee.

In the Pegu rocks of the Lower Chindwin district, mapped during the season by Mr. B. B. Gupta, there is a fossiliferous clay band in the Lawni Chaung, about two miles south-east of Saingde (22° 31′ 30″; 94° 30′). The fossils are very fragile but specimens of *Batissa crawfurdi* Noetl., *Unio* sp. and a ribbed variety tentatively referred to the Unionids, have been recorded. The same forms also occur in another clay band in the Hatti Chaung, near its junction with the Kyaukkwet Chaung.

The Pondaung beds have yielded one small jaw bone from a point on the cart tract between Chyinbyit and Aingma, about four miles 1½ furlongs west of the former place (22° 2′ 30″; 94° 41′ 30″). It has been referred to *Metamynodon* sp.

In the General Report for the year 1925 (Records, Vol. LIX, pp. 14-15) reference was made to what had been diagnosed as a fossil egg. It was descovered by Dr. Sheldon, Chief Inspector of Explosives, in the "Red Bed" to the north of the Yenangyaung oil-field. Further discoveries were made subsequently by Mr. Barber, who obtained 4 whole "eggs" and fragments of 19 broken ones from two horizons above the top of the "Red Bed" in the same locality. On examining these new specimens, Dr. Coggin Brown became convinced that they were not fossil eggs but the pupating cases of a large modern beetle. The specimens were taken home by Mr. Barber and submitted to specialists in the British Museum, who have confirmed Dr. Coggin Brown's opinion. It seems more than likely, therefore, that the specimen originally discovered by Dr. Sheldon is of the same nature.

Prof. A. C. Seward has examined some plant remains collected by Dr. J. Coggin Brown from the Province of Yunnan in Western China. The most abundant plant in the collection is a *Tæniopteris*, which agrees closely with *T. jourdyi*. Other forms represented are *Dictyophyllum*—possibly *D. remaurgi* or *D. fuchsi*—and a *Podozamites* which may be *P. distans*. The material is for the most part badly preserved, and it is difficult to make any very definite statement regarding the precise age of the plant beds, but Prof. Seward is inclined to think them Rhætic.

Prof. B. Sahni of the University of Lucknow has continued his work on the examination of plant fossils collected by the Officers of this Department throughout the year.

The Gondwana plant remains collected by Mr. Crookshank from the Mahadeva series in the northern part of the Chhindwara district,

as recorded in the General Report for 1927 (Records, Vol. LXI, p. 112) have been examined by Professor Sahni, who has made the following provisional identifications :—

Brachyphyllum mamillare Brongn.
Elatocladus tenerrima (Feist.).
E. cf. *jabalpurensis.*
Desmiophyllum indicum Sahni (see *Pal. Ind.*, New Ser., pl. V, fig. 61).
Ptilophyllum acutifolium Morr. sp. (especially numerous in the ferruginous specimens).
? Brachyphyllum or *? Pagiophyllum* sp.
Tæniopteris spatulata McCl.
Nilssonia sp.

Professor Sahni remarks that if the specimens all came from one horizon, one may with full confidence assign that horizon to the Jurassic. Most of the forms are well-known Upper Gondwana plants, and not one of them, so far as is known, has been recorded from the Lower Gondwana. Mr. Crookshank notes that the specimens from the top of Hasnapur Hill are near the base of the Jabalpur stage. Most of the others came from the south side of a large fault in the vicinity and belong either to the same horizon or to one a little higher up but well below the top of the group.

Among the specimens collected by Mr. Hobson from the Rajmahal Hills the following were identified by Professor Sahni :—

Ptilophyllum acutifolium Morr. sp.
Dictyozamites falcatus (Morr.).
Tæniopteris spatulata Mc Cl.
Coniferous wood (badly preserved).
Williamsonia sp. (petrified).

This, again, is an undoubted Jurassic assemblage. By far the most interesting type is the petrified *Williamsonia*, which Professor Sahni is further investigating in sections. The specimen is a Cycadean stem covered with an armour of persistent leaf-bases and bearing apically a flower very similar to *W. scotica* Seward (see *Phil. Trans. Roy. Soc.*, B. 1912, pp. 101-126).

Professor Sahni, who is undertaking a revision of the Gondwana plants of India, is of opinion that the palæobotanical evidence is

entirely in favour of the two-fold division of the Gondwana system suggested by Dr. Cotter in 1917 and hitherto officially adopted, and that there seems no reason for maintaining a Middle Gondwana division. He also concludes that the Parsora beds are Triassic and distinctly older than those of the Maleri stage, and that the Maleri stage is at least as young as Rhætic and should be transferred to the Upper Gondwana. For placing the Maleri stage at least as high as the Rhætic some independent support is afforded by a well-preserved coniferous wood collected by Dr. Cotter in 1916 (specimen K 19-336; horizon Maleri stage; locality ½ mile S. of Tiki, Beohari Tahsil, Rewah). The specimen proves to be a new species of *Mesembrioxylon*, a genus which, so far as present records go, ranges from the Jurassic to the Recent (Seward; Fossil Plants, Vol. IV, 1919, p. 173). Professor Sahni adds that Feistmantel (Fossil Flora of the Gondwana System, 1877, Vol. II, pt. 2, p. 16 and expl. of pl. IX; also Vol. I, pt. 4, p. 198—8) has recorded *Araucarites cutchensis and Palissya* (*Elatocladus*) *jabalpurensis* from beds at Naogaon, west of Maleri a locality which Dr. Fox assigns to the Maleri stage. These two species are characteristic Upper Gondwana fossils, both being abundantly represented in the Kota and Jabalpur stages as defined by Dr. Cotter.

Along with these Naogaon species Feistmantel names several other equally characteristic Upper Gondwana plants: *Ptilophyllum*, *Angiopteridium* (*Tæniopteris*) *spatulata*, etc. These are from Chirakunt, and he assigns them to the same (Maleri) horizon for reasons not stated. Whether this correlation is right or wrong, the fossils undoubtedly indicate an Upper Gondwana, and most probably a Jurassic, horizon. It seems that the list of plants (with the associated animal remains, *Hyperodapedon*, *Parasuchus* and *Ceratodus*) given by W. T. Blanford (*Rec. Geol. Surv. Ind.*, Vol. XVIII, p. 42) was based on this very collection from Naogaon and Chirakunt. Blanford refers the whole list clearly to the "Maleri Beds" as distinct from the Kota beds. It is important to ascertain beyond doubt the source of these plants, for if they were really from the Maleri beds, this fact would constitute the strongest evidence for a post-Triassic age. In any event, it is satisfactory to note that the three fossils, *Mesembrioxylon* from near Tiki and *Araucarites cutchensis* and *Elatocladus jabalpurensis* from Naogaon, although not broad-based as to their leaves, corroborate independently the testimony derived from the other sources.

During the year presentations of fossils were made to the following institutions :—

The Indian School of Mines, Dhanbad.—A second series embracing representatives of most of the Invertebrate orders and extending from Cambrian to Pliocene.

The Gokhale Memorial Girls' School.—A similar series including a few representatives of the various subdivisions of the Invertebrate Animal Kingdom and two specimens of plant fossils.

The Birla Bidya Peeth Institution, Pilani, Rajputana.—A series almost similar to that presented to the Gokhale Memorial Girls' School.

The Curator, Patna Museum.—A series embracing representatives of most of the Invertebrate orders and extending from Devonian to Pliocene and one specimen of a plant fossil.

The Sedgwick Museum, Cambridge, through Dr. F. R. Cowper Reed.—A collection made by Dr. Reed, Dr. Cotter and Mr. Lahiri from the Salt Range.

In addition to those mentioned, donations of fossils were received from the following :—

Mr. W. R. Hay, Political Agent, S. Waziristan.—Specimens of *Assilina spira* and *Alveolina* sp.

Mr. C. T. Trechmann—Specimens of *Rudistæ* and gastropods from the Turonian of France.

Messrs. E. P. Vachell and R. Morrison of the Burmah Oil Company.—Specimens of *Orbitoides apiculata*, *O. socialis*, *Semisolarium* sp. cf. *moniliferum*, *Hautkeria striata* and *Exogyra* sp. cf. *overwegi*, etc., from the Nishpa Shales (=? Hemipneustes beds or Mæstrichtian), half-a-mile S.10°E. of Payori Mela, Sherani.

Mr. T. Copeland, Offg. Revenue Commissioner, North-West Frontier Province, Peshawar.—Specimens of *Productus indicus*, *P. lineatus*, *Spirifer musakhelensis*, and many other specimens from the Permo-Carboniferous and Lias of the Salt Range.

The American Natural History Museum, Palæontological Department.—From the Snake Creek Formation S. of Agate, Nebraska, five specimens of *Merycohippus*.

Prof. H. M. Page of Poona.—An interesting reference set in a cabinet, of about four hundred European Invertebrate, Vertebrate and Plant fossils.

World Power Fuel Conference.

Owing to the unavoidable absence of the High Commissioner for India from London in September, Sir Edwin Pascoe was asked to represent India at the Fuel Conference held at the Imperial Institute. As the papers and discussions of this important gathering are to be published *in extenso* very shortly, it would serve no purpose here to recapitulate the ground covered; it would, in fact, take many volumes of this periodical to do so. Although India's fuel problems are of a peculiar character and largely domestic, it is important that she should keep in close touch with all modern tendencies of thought and research upon such an international subject. The World Power Fuel Conference provided an ample opportunity for such intercourse.

Empire Mining and Metallurgical Congress.

Mr. H. C. Jones was deputed to represent the Department at the Second (Triennial) Empire Mining and Metallurgical Congress held in Canada in August and September 1927, and at the conclusion of the Congress was permitted to spend nearly five weeks examining the iron ore ranges of the Lake Superior district of the United States of America. Mr. Jones returned from leave in March, and his report on the Congress was therefore not available for review in the General Report for 1927.

The Congress opened at Montreal on August 22nd, 1927, and closed at Quebec on September 27th, 1927. During this period, two simultaneous tours in special trains were arranged, and meetings and technical sessions were held in the principal cities of Canada. Mr. Jones elected to take the tour which visited the chief mining centres of Ontario, Quebec and Western Canada, and during the course of the tour attended meetings and technical sessions held at Montreal, Toronto, Winnipeg and Vancouver. The Congress was attended by representatives of all the important mining, metallurgical and allied institutes and societies, representatives of the principal geological surveys, mining departments, mines and metallurgical works in the Empire. In addition to the papers and discussions at the meetings and technical sessions, the Congress provided an important opportunity for the interchange of ideas, and for informal discussions on matters connected with mining, metallurgy and geology, in various parts of the Empire.

The Congress parties were shown over the principal metallurgical works and refineries. Visits were paid to numerous mines, and opportunity was taken to examine the underground workings when possible. Geological parties were occasionally made up and taken round mining areas, under the guidance of a local geologist.

At the conclusion of the Congress, Mr. Jones visited the well known Lake Superior iron ore deposits, in order to compare them with our Indian deposits. Mr. Jones has submitted a report on his visit to these deposits, and this will be published shortly in the Transactions of the Mining and Geological Institute of India.

ECONOMIC ENQUIRIES.

Asbestos.

Kashmir.

Thin veins and stringers of Asbestos were found by Mr. D. N. Wadia to occur in association with some epidote veins traversing Panjal Trap in the north-western corner of the Shamsh Abari mountain mass in the Karnah *tehsil*, Kashmir.

Barytes.

Singhbhum, Bihar and Orissa.

Dr. Krishnan notes the occurrence about half-a-mile south-west of Kolpotka (22° 2′; 85° 1′) in Singhbhum, close to the Gangpur border, of two zones of sericite-schist in which occur veins of barytes formed by replacement. In the southern band the barytes occurs in ramifying veins over a tract 500 yards long and 150 yards wide. The veins conform more or less to the schistosity, the dip being from 70° to 75° in a direction S. 40° E. The barytes is being worked open-cast, and the picked white lumps obtained form about 5 to 7 per cent. of the material extracted. The amount extracted is about 2 to 2½ tons daily and is sent in cooly-loads to Jaraikela for despatch to Calcutta. The northern zone has also been tested, but proved to be too poor in barytes for profitable working.

Simla Hills.

Mr. Auden states that in the Simla Hills, at 77° 1′ 15″ by 30° 58′ 30″, and occurring in the Simla Slates, there is a small discontinuous vein of Barytes. This has scarce galena which is said to be argentiferous. It was worked a long time ago, but would probably not repay further working.

Building Materials.

Lower Chindwin District, Burma.

Large quantities of basalt are quarried from the Shahyindaung hill, about three miles north of Alon (22° 15′; 95° 5′) in the Lower Chindwin district. At Okpotaung (22° 29′; 95° 10′ 30″) the rock, according to Mr. V. P. Sondhi, is vesicular and inferior in quality to that of Shahyindaung but is quarried extensively on behalf of the Public Works Department of the Lower Chindwin and Shwebo districts.

At Kandaw, near Alon, quartz gravel occurs in large local concentrations near the surface of the alluvium. It is used as ballast over part of the Ye-U branch of the Burma Railways. The basalt which is used for road-metal between Budalin and Ye-U, is obtained from the Inde Crater.

Myitkyina District, Burma.

Dr. Chhibber reports that the bridges under construction along the Mogaung-Kamaing road, Myitkyina district, are being built of local Tertiary sandstones. The rock is soft and felspathic and soon decays in the humid climate, though it possesses the advantage of being easily shaped and dressed. The minor causeways of the mule-track joining Kanchaung and Tawmaw, between Namting (25° 38′; 96° 27′ 29″) and Lonkhin (25° 39′; 96° 22′) have been made of the same rock.

Small outcrops of limestone, metamorphosed to marble in places, are common in the Jade Mines region. The rock has been used for building construction and is also burnt for lime around Kamaing.

The roads in Myitkyina town are metalled either with material derived from boulders of igneous rocks from the banks and low cliffs edging the Irrawaddy there, with serpentine from the neighbouring hills, or with laterite quarried between Myitkyina and Pidaing: the serpentine, although binding well, crumbles easily under heavy traffic.

Serpentine, crystalline schists and vein quartz (from the latter), furnish the road metal for Mogaung town.

Marble: Mewar State, Rajputana.

The Raialo marble in Mewar (Udaipur) affords good ornamental stone of pink, salmon, cream and white colours, and in large quantity. It is a saccharoidal dolomite, of uniform texture, thickly bedded, sparingly jointed, and free from impurities such as argillaceous bands and calc-silicate minerals. In the occurrences south of Udaipur

City seen by Dr. Heron this season, coloured varieties predominate over white, but in the northern localities—Rajnagar[1] for instance—it is nearly all white. Suitable localities are (1) between Devi Mata (24° 24′ ; 73° 45′) and Kalakot (24° 29′ ; 73° 45′), (2) east of Babarmal (24° 25′ ; 73° 46′), and (3) Pangamra (24° 0′ ; 74° 8′) ; the last-named is too far from any railway or centre of population to be of present utility.

Chromite.

Chromite is associated with the peridotites and serpentines of the Jade Mines region in Myitkyina. Dr. Chhibber found a number of boulders of this mineral, some of which measured over 3 feet in diameter, about $2\frac{1}{2}$ miles north-east of Tawmaw (25° 41′ 13″ ; 96° 15′ 28″) on the road to Sanhka Hka. Another small occurrence exists about $1\frac{3}{4}$ miles to the north-east of Tawmaw, on the same track. Both are believed to be segregation patches in the local ultra-basic rocks.

Myitkyina District, Burma.

Water worn boulders of chromite are sometimes found in the jadeite workings of the boulder conglomerates in the Uru river.

A specimen from Hotag hill, Silli (23° 21′ : 85° 50′ 30″) Estate in the Ranchi district, brought to this office for examination by Mr. K. B. Dutt of Calcutta, was identified as chromite. In thin section (No. 18,131) the chromite is seen to be associated with serpentinous minerals. So far as known, this is the first recorded occurrence of chromite in the Ranchi district.

Ranchi District, Bihar and Orissa.

A specimen from Baida Chauk, about 5 miles from Mandar Hill Station (24° 48′ 30″ : 87° 1′ 30″) in the Bhagalpur district of Bihar and Orissa, was sent for identification to this Department by Mr. T. Chowdhury of Jamtara, East Indian Railway, and was found to contain chromite.

Bhagalpur District, Bihar and Orissa.

Clay.

A large lenticle of tenacious clay, enclosed in Irrawadian rocks just to the east of Yedwet (95° 11′ ; 22° 32′), is used extensively in the manufacture of brick-red earthernware which commands a considerable local market.

Lower Chindwin District, Burma.

[1] Gen. Rep., 1926, *Rec., Geol. Surv. Ind.*, LX, p. 48.

Chhindwara District, Central Provinces.

White clays are a feature of the Jabalpur beds in Chhindwara. They usually occur in layers 2 to 3 feet thick, but in one place, one mile south of Muria (22° 45′ 30″; 79° 7′ 30″), they attain a thickness of 10 feet. From tests made Mr. Crookshank is of opinion that these clays are refractory clays, probably suitable for the manufacture of fire-bricks. As the principal deposits are not more than 60 miles by rail from the Jubbulpore potteries, they may one day have an economic value. The localities specially mentioned are (1) between Saonri (22° 43′ 30″; 78° 59′) and Hasnapur hill (22° 46′; 79° 1′ 30″) in the Narsinghpur district, (2) to the east of Kundali (22° 47′; 79° 14′), and (3) one mile south of Muria. It is not likely, however, that much use will be made of these clays as long as the Jubbulpore pottery works are able to obtain satisfactory clays from the Jabalpur beds at Jubbulpore itself, so that the localities mentioned by Mr. Crookshank must be regarded as containing reserve supplies, in so far as prospecting operations, when necessary, may prove these clays to be present in quantities worth attention.

Coal.

Lower Chindwin District, Burma.

At least four coal-seams were noticed by Mr. B. B. Gupta in the Yaw rocks of the area surveyed by him in the Lower Chindwin district (see page 106). The topmost seam appeared to him to be the best; at least three feet of good coal could be obtained from it. To the east of Mahu (22° 44′ 15″; 94° 35′ 30″) only one seam was observed; it is of a very low grade and is described as no better than carbonaceous shale.

Myitkyina District, Burma.

Three coal-seams, varying in thickness from 14 to 20 inches, were found by Dr. Chhibber about a furlong to the north-north-east of Makapin, (25° 28′ 53″; 96° 13′ 4″) in the Myitkyina district. They are intercalated in almost vertical greyish carbonaceous shales, with a few layers of sandstone of Tertiary age, and have been traced for about 100 yards. The lignitic coal appears to contain pyrites and is worthless from an economic point of view, owing to the thinness of the seams and their highly crushed condition.

Stumps of lignite have also been found in a number of localities around Hwehka (25° 29′ 3″; 96° 16′ 43″), as at Zibyugon (25° 28′ 45″; 96° 17′ 41″).

"Coal" in the Vindhyan System, Rhotasgarh, United Provinces.

For the last hundred years there have been periodical reports of the discovery of coal in strata of the Vindhyan system. In every instance the beds referred to have proved to be one or other of the bands of black carbonaceous or pyritic shale which occur at the base of the Upper Vindhyans or in strata of the Semri series (Lower Vindhyan). In each case it has been shown that no workable coal is present in this formation. In fact no coal, recognisable as such, has been noted from any of the occurrences. The latest rumour of coal in the Vindhyans comes from the Bijaigarh shales in the scarp facing the Son valley a few miles west of Rhotasgarh. Late in January 1928, Dr. C. S. Fox, who was on his way from the Daltonganj coal-field to the Son valley in the Mirzapur district, stopped at Japla and was able to secure specimens of the black shales which were said to be evidence for the belief of the occurrence of coal. The material is a black carbonaceous shale of the following composition :—moisture 1·44 per cent., volatile matter 9·10 per cent., fixed carbon 12·28 per cent. and ash 77·1 per cent. The specific gravity of the shale is 2·407 and the ash is of a light chocolate colour.

A certain amount of scientific interest does, however, attach to the specimens obtained by Dr. Fox, in that small lenticles of bright, anthracitic coal do occur in the shales. The amount of such material is exceedingly small. With great care and difficulty only 5 grams were abstracted from the several pounds of shale brought to Calcutta. This bright coal, or vitrain, gave the following analysis :—moisture 4·24, volatile matter 11·34 per cent., fixed carbon 65·62 per cent., and ash 18·80 per cent. The specific gravity, 1·662, is higher than it should be according to Dr. Fermor's formula (see Records, vol. LX, pp. 315-316). Much of the ash is probably extraneous matter which was still attached to the particles of bright coal. This evidence of coal in strata of early Palæozoic age, although of no economic importance, is worthy of note from a scientific point of view.

Copper.

Singhbhum, Bihar and Orissa.

During the field-season Dr. J. A. Dunn made a short study of the copper-bearing lodes at Rakha Mines preparatory to the resumption of the systematic survey of the portion of Singhbhum in which the Copper Belt is situated.

The ancient workings, along the site of which the mine has been developed, go down to a depth of over 200 feet in places. The Rakha lode itself was found to crop out at only one point, where it crosses a stream to the N. W. of the main shaft. Here it is seen to be a typical gossan, a vuggy ferruginous quartz, with a little native copper and a few specks of malachite. To the S. E. of the main shaft the position of the lode in a stream is indicated by copper staining in the stream water. The Rakha lode in places reaches a width of 3 feet, but the average is 9 or 12 inches. As a rule it is represented by a solid band of sulphides (usually chalcopyrite and pyrrhotite) with a varied proportion of white quartz. Sulphides disseminated in both foot and hanging walls increase the stoping width of the lode up to 6 feet. As a solid vein the lode is found over a distance of 1,400 to 2,000 feet at different levels. It is not always persistent but sometimes thins out and "makes" again a foot or so to one side. At the south end of the lode another lode on which very little development work has been done commences about 50 feet to the east. Down to a depth of 900 feet on the incline the Rakha lode has been stoped out of all ore containing over 3 per cent. of copper.

The Rakha lode dips on an average 47° to the N. E. the strike being N.W.-S. E., and the lode striking and dipping with the country. Dr. Dunn reports that the country rock varies from chlorite-quartz-schist to quartzite by silicification, and there is also a gradation to muscovite-quartz-schist by decrease in the amount of chlorite and increase in the amount of muscovite. The chlorite-quartz-schist is, however, the main rock. Frequently it contains a very considerable amount of tourmaline, and in the lower levels biotite is abundant. Many of the specimens contain much blue hornblende.

The lode is formed along a shear line in the chlorite (and biotite) quartz-schist, and often contains fragments of the enclosing country rock. Along the hanging wall an autoclastic conglomerate is quite often found, formed by the crushing of a quartzite band. The lode materials consist of quartz, chlorite, apatite, chalcopyrite, pyrrhotite and magnetite. The quartz and apatite are crushed in an extraordinary fashion and the sulphides are interstitial to the crushed minerals. Dr. Dunn concludes that silicification of the lode channel preceded the deposition of the sulphides in their present position, and that this silicification was followed by acute movement and crushing. The sulphides were deposited in their present position

after crushing, or possibly during the differential movement. This fact does not necessarily determine the actual time of entry of the sulphides into the lode. They may have accompanied the quartz during silicification and prior to crushing, and have moved into their present position, interstitial to the other minerals, as a result of crushing. So far it has not been possible to discover positive evidence of crushing within the sulphides. It is believed that the sulphides accompanied the quartz, apatite and chlorite, but that owing to their comparative instability and greater ease of movement under pressure, they have moved into the interstices.

The origin of the chlorite (and biotite) quartz-schist forming the country rock is not clear. Associated with it is a good deal of altered epidiorite, and to the S. W., running parallel to the schists, there is a wide belt of epidiorite which Dr. Dunn thinks may be correlated with the Dalma volcanics of north Singhbhum. These schists, forming the country rock to the Rakha lode, are similar to many of the fine-grained schists in north Singhbhum which were found to be altered basaltic tuffs; in fact they appear to be identical with those which immediately underlie the Dalma volcanics in north Singhbhum.

Dolomite (see Limestone).

Engineering and Allied Questions.

Sunkh River crossing, Bihar and Orissa.

Of the two sites suggested for the crossing of the Sunkh river along the proposed Ranchi-Sambalpur road, that near Karanjia in the vicinity of the present rough cart-road into Gangpur is made up of some 1,500 feet of sand. There are apparently no outcrops of rock, and screw piles would be necessary. The alternative site is N. E. of Alu Pahar and about 200 yards S. of a small village named Galatoli on the west bank of the river. Dr. Dunn found that gneissic-granite crops out across the whole width of the river, which is here some 1,100 feet. The rock is only slightly affected by partings, and these are almost confined to the two banks. As a foundation for a bridge, the site is eminently suitable, but, since it occurs at a point where the river has commenced a drop of 400 feet in 8 miles, the piers of the bridge will have to be strong enough to stand strong rapids.

In the General Report for 1927, a summary is given of the geological aspects of the Lewa-Pyagawpu and other schemes for the supply of water and hydro-electric power to Rangoon. The Consulting Engineers engaged by the Government of Burma for this work returned to the Province again to investigate the possibilities of a scheme of water supply for the city only. Mr. P. Leicester was deputed to examine geologically certain reservoir areas and dam sites in this connection.

Rangoon Water Supply; Pegu District, Burma.

The areas examined lie on the Survey of India one-inch-to-the-mile Sheets 94-C/3, 94-C/7 and 94-C/8 in the Pegu district. Among the schemes investigated by the Consulting Engineers during 1928, Mr. Leicester submitted a geological report on the following:—

(1) Wagyaung Reservoir Area with the auxiliary Mahuya Chaung Reservoir Area.

(2) Shwele-Chaung Reservoir Area with the auxiliary Lagunbyin Chaung Reservoir Area.

(3) Intagaw South Reservoir Area with the auxiliary Intagaw North Reservoir Area.

(1) The Wagyaung and Mahuya Chaung reservoir areas lie on Sheet No. 94-C/3, between longitudes 96° 5′ and 96° 15′, and latitudes 17° 20′ and 17° 30′, on the southern fringe of the Pegu Yoma about 40 miles due north of Rangoon. It is proposed to impound the waters of the Ngamoyeik Chaung or Paunglin Chaung—the upper waters of the Pazundaung Creek—and its tributaries by means of a dam about half-a-mile N.W. of Kyawzaw village (96° 11′ 22″; 17° 21′ 31″) and a stop-gap dam half-a-mile south of Tinzeik village (96° 9′ 38″; 17° 21′ 18″). To obtain the required high-water level certain portions of the southern and eastern ridges have to be banked up. The impounding area thus obtained is of considerable size and the Consulting Engineers consider that this reservoir, if constructed, would furnish all the water requirements of Rangoon for some very considerable time to come.

The Mahuya Chaung area borders the Wagyaung reservoir area on the east, and forms a scheme for adding to the catchment area of the Wagyaung reservoir in the distant future. A dam would be constructed about 1 mile south of Mezali Kwin (96° 12′ 30″; 17° 23′ 16″) to impound the waters of the Mahuya Chaung and its tributaries; a cut would also be made to convey the water into the Wagyaung reservoir.

The impounding area of the Wagyaung reservoir lies to the east of a southerly projecting ridge of the Pegu Yoma and comprises that portion of the valley of the Ngamoyeik Chaung which stretches from the village of Onhnebin in the north to half-a-mile north of Kyawzaw village in the south. On the west and north it is bounded by the slopes of the Pegu Yoma while on the east and south are broad low ridges belonging to the foot-hills of the Yoma. The ground level at the dam site is about 75 feet above sea level and the intended low and high water-levels of the reservoir are 95 feet and 115 feet respectively.

Excepting the slightly raised ground in the neighbourhood of the Tinwin Chaung and the stream-beds the floor of the reservoir is covered with a layer of impermeable alluvial clay of sufficient thickness to prevent loss of water by percolation into the porous strata of the Irrawadian series which it overlies. At the main dam site the thickness of alluvial clay is about 15 feet and, though it decreases in thickness as one proceeds northwards up the valley, Mr. Leicester finds it improbable that the depth of good clay is less than 4 feet anywhere within the impounding area except where it thins out against the bottom of the ridges. The slightly elevated ground lying between Wagyaung Chaung and the Tinwin Chaung and the gradually sloping ground north of the Tinwin Chaung, about one mile N. N. W., of Wagyaung village, is not covered by alluvium. The rock here belongs to the Irrawadian series and is to a certain degree permeable.

The rising ground close to the right bank of the Ngamoyeik Chaung is here capped by impermeable lateritic clay, but just to the west where the Wagyaung-Pokta cart track crosses a tributary of the Ngamoyeik Chaung, the ground is very sandy and permeable. How much water may be lost through percolation over these areas Mr. Leicester is unable to say but it seems improbable that any appreciable amount would be lost on this account except over the sandy tracts; even at these localities it is probable that in time the voids of the porous sands will become filled with silt carried into the reservoir by the muddy streams.

Within the impounding area the streams have everywhere cut through the alluvial clay, exposing in places rocks of the Pegu and Irrawadian series beneath; on either bank, resting above the rock, is a belt of fine sandy silt. At the main dam site no rock is exposed and the stream flows on a layer of silt 30 feet in depth between

banks of silt 25 feet high. The breadth of this band of silt varies from a few feet to more than 500 feet at the main dam site. The silt is extremely fine, being composed of very small grains of quartz and flakes of mica, and, though porous, when once saturated it should not allow any appreciable loss of water through percolation.

The beds of the streams are covered by a layer of silt where actual rock is not exposed, and stagnant pools which are to be found in hollows in the stream-beds stand as evidence of the impermeable nature of the material. Furthermore, in the process of time the silt entering the reservoir would collect in hollows of the reservoir, such as the stream-beds, and form an ever increasing protective covering.

Mr. Leicester does not consider it necessary to line the stream beds for the prevention of leakage but in his opinion it would be advisable to protect the bed of the Ngamoyeik Chaung and the area of silt on either bank for a distance of at least 1,000 feet from the dam site upstream, to prevent percolation beneath the dam. The breadth of the band of silt at the dam site is about 550 feet and he suggests that the breadth of the strip to be protected against leakage should be 600 feet.

At the main dam site there is a layer of alluvial clay stretching across the greater part of the dam line, while, in the centre, embracing the bed of the Ngamoyeik Chaung, is a trough-shaped belt of fine silt. The alluvial clay attains a thickness of 15 feet on the left bank and 17 feet on the right bank of the stream and thins out against the ridges on either side, but fortunately, here at the sides, clays of the Irrawadian series underlie the alluvial clay. Towards the centre of the line, however, the underlying rock is sand, varying from fine clayey sand to clean coarse flowing sand, and the trough-shaped band of silt through which the Ngamoyeik Chaung flows overlies loose porous sand. The thickness of the alluvial clay-covering is diminished by two small streams to the left of the Ngamoyeik Chaung and Mr. Leicester considers that these depressions should be filled in, both under the dam and for some distance upstream.

The silt trough should, in Mr. Leicester's opinion, be protected in some way, for the silt is porous and unstable. It would be of no avail to excavate the whole of the silt, for in so doing the far more porous sands beneath would be exposed and Mr. Leicester suggests that the silt be excavated to a depth of, say, 15 feet and

the hollow be filled with clay. The silt may be expected to settle even under the weight of an earthen dam, for beneath it occur the loose sands mentioned above. How far the layer of clay overlying the sands will be able to stand the weight of an earthen dam and the pressure of 40 feet of water behind the dam, it is difficult to say.

With regard to surrounding ridges, that to the east, on the left of the Ngamoyeik Chaung, is capped by a layer of laterite clay for some distance, but the termination of the western ridge is sandy and permeable. Since, however, these ridges do not attain the requisite height for some considerable distance on either side of the dam line they will have to be banked up and in so doing their slopes should be protected right down to the level of the alluvial clay at the foot. In this way the ridges might be incorporated as the back of one long continuous dam over such parts of the ridges as are permeable.

The western ridge in the lower part of the reservoir area is composed of sandstones and shales of the Pegu series. The sandstones are porous but the impermeable shales predominate and the dip of the rocks is here easterly, that is to say inwards. Moreover the slopes of the hills are covered with a thick layer of clayey impermeable talus. Farther north bordering the narrow portion of the reservoir the rocks belong to the Irrawadian series but the general dip is easterly and the covering of talus thick.

Certain portions of the southern and eastern ridges are sandy and permeable and in his report Mr. Leicester points out that at these localities the ridge should be protected against leakage down to the level of the alluvial clay at the foot. This particularly applies to the southern portion of the eastern ridge, where the Irrawadian rocks dip eastwards and outwards from the impounding area. The structure in the ridge farther north is more satisfactory since here the ridge embraces both arms of a syncline and the strata dip westwards on the east side of the ridge.

On either side of the dam line the ridges are sandy and porous, and, since for some considerable distance along the eastern and western traverse the ridges do not attain the requisite height, these portions of the ridges would be incorporated in a continuous earthen *bund*.

Situated 12,500 feet to the west of the main dam site near Tinzeik village is a narrow gap the bottom of which is only a few feet below

the intended high-water level. Provided reasonable precautions are taken in the construction of the small gap-dam here, there need be no fear of any appreciable leakage. The spillway would be constructed on the banked up portion of the eastern ridge.

Mr. Leicester's conclusions are that the greater part of the floor of the reservoir is water-tight and the western ridge is geologically satisfactory. The northern part of the eastern ridge and the greater part of the southern ridge, though somewhat permeable, should not be the cause of any appreciable loss of water, but the southern part of the eastern ridge and certain parts of the southern ridge are porous and need to be made water-tight. Geological conditions at the main dam site are bad but if various precautions are taken it should be possible to construct a satisfactory earthen dam. The site is unsuitable for a concrete dam.

With regard to the Mahuya Chaung auxiliary reservoir the impounding area is smaller than that of the Wagyaung reservoir but the catchment area is considerable. It is situated parallel to and to the east of the Wagyaung reservoir, the eastern ridge of the latter being common to the two reservoirs.

The floor of the reservoir which is rather uneven is covered by impermeable alluvial clay. The dam site is about one-and-a-half miles north of the main dam site for the Wagyaung reservoir and the western ridge consists of the northern and more satisfactory portion of the eastern ridge of the Wagyaung impounding area. The eastern ridge is broad and lateritic and should be comparatively water-tight.

At this dam site conditions similar to those at Wagyaung reservoir main dam line may be expected.

The Mahuya Chaung reservoir will only be constructed at such time when the supply of water from the Wagyaung reservoir ceases to be sufficient for the needs of Rangoon. The purpose of the reservoir will not be that of storage but rather of adding to the catchment area of the Wagyaung reservoir. The water from the Mahuya reservoir impounding area would flow into the Wagyaung reservoir by means of a cut excavated across the dividing ridge. This cut should be lined to prevent slips.

(2) The Shwele Chaung and Lagunbyin Chaung reservoir areas lie on Sheets 94-C/7 and 94-C/8 between longitudes 96° 20′ and 96° 25′, and latitudes 17° 10′ and 17° 25′, among the low ridges south of the Pegu Yoma about 30 miles due N.N.E., of Rangoon.

This scheme would necessitate impounding the waters of the Shwele Chaung and its tributaries by means of a dam situated by the village of Gonnyindan Anauk (96° 23′ 38″; 17° 12′ 24″). The catchment area would later be increased by the construction of a dam across the Lagunbyin Chaung just below its junction with the Kyat Chaung (96° 21′ 25″; 17° 18′ 30″) and the water thus impounded would be conveyed to the Shwele Chaung reservoir by means of a cut across the separating ridge.

The floor of the Shwele Chaung reservoir is covered by a layer of alluvial clay and is therefore water-tight. At the dam site this layer of clay appears to be about 29 feet in thickness near the centre of the dam line, and thins out at the bottom of the ridges, but it is possible that some of this belongs to the Irrawadian series. Beneath the clay are sands, sandy clays and clays of the Irrawadian series.

The western ridge is broad and higher than the eastern ridge. It appears to be lateritised over most of its length but the spurs are inclined to be sandy. Less than half-a-mile north of the dam line there is a sandy spur in which the best wells of Gonnyindan village are located, and from which issues a perennial spring. Though the amount of water likely to be lost through this spur is not great it would be as well to make it water-tight.

All the test pits sunk on the eastern ridge show laterite clay, or laterite. Here the process of lateritisation has progressed further than in the southern portion of the western ridge, and appears to have rendered this ridge more or less water-tight.

The dam line, which is over a mile in length, rests for the greater part of its length on alluvial clay of considerable thickness. This alluvium thins out against the hill-slopes but reaches a depth of about 30 feet near the centre of the dam line. Actually in the centre of the line is a low spur which stretches from the north and disappears a few yards south of the dam line. Test pits sunk in this spur reveal impermeable laterite clay. The ridge to the east is composed of impermeable laterite clay and, just above the east end of the dam line, is capped by laterite.

A bore sunk through the western ridge at the west end of the dam line reveals sandy material down to a depth of 28 feet after which clay is struck. The sand is porous and there is likelihood of loss of water through this part of the ridge and Mr. Leicester considers that the aim of the dam here should be carried well into the

side of the ridge and that the ridge in front of the dam should be protected and made water-tight for some distance, say, 400 feet.

At the foot of the western ridge a boring has revealed impermeable clay beneath a covering of sand and sandy clay 12 feet in thickness. This sandy material should be removed and the core of the dam should be sunk into the clay.

At the spill-way test pits have shown that laterite clay underlies laterite sand. The laterite sand which is probably not more than 10 feet in thickness should be removed and the foundations and arms of the spill-way should be sunk in the laterite clay. This is, from a geological standpoint, the most satisfactory reservoir area examined and though the site is unsuitable for a concrete dam Mr. Leicester considers that by the construction of an earthen dam a sufficiently water-tight reservoir could be formed.

The Lagunbyin Chaung reservoir is not intended for storage but would be constructed in order to enlarge the catchment of the Shwele Chaung reservoir and the water would be conveyed into the Shwele Chaung reservoir by means of a cut.

As in the case of all the other reservoir areas the floor of the Lagunbyin Chaung reservoir is covered with a layer of alluvial clay which is here about 5 feet in thickness overlying sand and sandy clay. Near the dam line both the western and eastern ridge are sandy and porous. The foot of the western ridge is particularly bad.

The height of the dam would be small and the loss of a certain amount of water from this reservoir is, since it is not a storage reservoir, not a very serious matter. Nevertheless, Mr. Leicester reports, the geological conditions here are bad, and if even a low earthen *bund* were constructed every precaution would have to be taken to ensure its stability. The arms of the dam would have to be carried some way into the ridges and it would be necessary to protect the ridges against percolating water for some distance either side of the dam. The rock at the cut is sandy laterite clay beneath a thin capping of laterite rubble and this material should not be difficult to excavate.

(3). The Intagaw South and Intagaw North reservoir areas lie on Sheet 94-C/8 between longitudes 96° 25′ and 96° 30′ and latitudes 17° 10′ and 17° 15′ among the lower ridges bordering the deltaic alluvial plains about 30 miles due N.E. of Rangoon and 43 miles from Rangoon along the Rangoon-Pegu road. This scheme pro-

poses impounding the waters of the Kyi-bin Chaung by means of a dam situated about one mile east of Pyinma-ngu village (96° 26′ 22″; 17° 10′) and a small stop-gap dam near-by to the west. Both reservoirs are small and are only to be considered as a stepping stone towards the Yunzalin hydro-electric scheme, the pipe-line of which would pass close by.

The impounding area of the Intagaw South reservoir is small and has practically no external catchment area. The streams of the low ridges around the reservoir contribute a certain amount of water during the "Rains" but they cease to flow very soon after the close of the monsoon.

It is clear that a small reservoir, such as this, relying for its supply of water on short seasonal streams and the rain falling upon its surface, must be made water-tight since even a small loss of water would be serious. There is a thick covering of alluvial clay over the floor of the reservoir. As is usually the case this layer thins out against the ridges but this is not very noticeable since the clays of the ridges themselves are not easily distinguished from the alluvial clay. There are a few sandy spurs such as the eastern ridge south of the new dam line but the greater part of the ridges are lateritic, laterite clay being prevalent.

A number of test pits, sunk on the ridges, revealed the irregular lenticular nature of the lateritic clays and sands composing them. The low points are more often sandy and the rounded higher parts of the ridges are usually capped by laterite.

The ridges are low and not very broad, and in some cases the laterite cap overlies lateritic sand and does not stretch right down the foot of the ridge on either side but leaves a clear path by which water in the reservoir would be lost. Mr. Leicester remarks that it should be possible to protect the lower slopes of certain parts of the ridges to render them water-tight, but it would first be necessary to locate all such parts needing this treatment. To do this would necessitate a trench or a large number of pits along considerable lengths of the ridges to ascertain the permeable portions—an expensive undertaking—while, to omit such precautions would be an unjustifiable risk.

The first dam line selected in the Intagaw South area had to be abandoned on account of the sandy nature of the ridge at the east end and unstable water-bearing sand at its foot. The western end of the second alternative dam line runs from the same point as that

of the old dam line but the eastern end terminates on a spur farther to the north than that of the old line. The upper part of the ridge on the west is composed of water-tight and compact laterite clay, but the ground at the foot is sandy. A bore, sunk here, passed through sand down to a depth of 38 feet; some of this sand was coarse and very porous and the core-wall of any dam built here would have to be carried well into the clay beneath. The middle portion of the line, which passes over the flat alluvium of the rice fields, is good and conditions at the foot of the eastern spur are favourable. On the spur, however, test pits and bores show that beneath a six-foot capping of laterite clay there is a layer of porous laterite sand, and if a dam were constructed here, the *bund* should cover and so protect the inside of the spur.

In the western ridge just north of the end of the main dam line is a small gap that would have to be dammed. The ridge at the south-east side of the gap is composed of impermeable laterite clay but in the centre of the line the ground is sandy and porous, probably to a considerable depth. The test pit on the ridge at the north-western end of the gap dam line reveals lateritic sand above and below a layer of laterite 3 feet thick lying 4 feet below the surface. Conditions here are considered unfavourable for the construction of a stable water-tight dam.

Test pits sunk at the spill-way show laterite clay beneath a six-foot layer of sandy material. The foundations of the spill-way would have to be carried well down into the clay.

In his report Mr. Leicester concludes that, unless expensive investigations and elaborate and costly protective measures are resorted to, the construction of this reservoir is not justifiable in view of the risk of loss of water through the ridges of the impounding area.

The Intagaw North or Mogwa Chaung reservoir is very small and merely serves as an addition to the Intagaw South Reservoir. Here as in the other reservoir areas the floor is covered by impermeable alluvial clay. The ridges are more lateritic and water-tight than those the southern area. At the dam line the ridges are composed of laterite clay and in places sandy laterite clay or laterite, but the top of the north-east end of the dam line is sandy. The ridges here are broad and if suitable precautions were taken to render impermeable the ridge at the north-east end of the dam line Mr. Leicester considers that a sufficiently water-tight reservoir

could be constructed. This area, however, is very small and its construction apart from the Intagaw South reservoir would not be practicable.

Mr. Leicester was deputed to examine and report on the geological conditions at the dam site of the proposed Wundwin Tank at Leinbin 1½ miles west of Wundwin village, Meiktila district (96° 3′ 22″; 21° 5′ 16″. Sheet 93-C/4.).

Wundwin Tank, Irrigation Project, Meiktila district, Upper Burma.

Both the *bund* and the weir of the old Wundwin Se, which is situated half-a-mile west of Wundwin, broke during the floods of 1926. It was then proposed, that a new tank should be formed by the construction of a dam a little higher up the Wundwin Chaung near Leinbin village.

A number of trial pits and borings were sunk along the dam line by the Irrigation Engineers and it is reported that hard brown clay and compact sand-rock were met at reasonable depths in some of the borings. In other instances, however, on either bank, sand, sand-rock, clay and *kankar* impregnated with efflorescent salts were met. Samples from certain of the pits were sent to the Chemical Examiner to the Government of Burma for analysis together with samples from the *bunds*, weir foundations etc., of other tanks in the district where breaches had occurred. The percentages of soluble salts contained in the samples from the Wundwin dam line were found to be large and greater than in any of the samples from the other works.

At the site of the proposed works the Wundwin Chaung has cut through a low sandy ridge which is a northerly continuation of that at Thazi (Sheet 93-D/1). This ridge is an inlier of Upper Pegu or Irrawadian beds cropping out through the alluvium of the plains and is composed of hard compact sand, sand-rock, gravel and beds of clay; in places both the sand and the clay are highly impregnated with efflorescent salts, principally sodium carbonate.

Below the water-table where the ground is damp at the foot of the ridge, the sand and clay become very sticky owing to the presence of the salts. Pits at the foot of the ridge on either bank of the stream reveal quicksand which appears to extend to some depth. The right bank is chiefly sandy and the clay and sandy beds on the left bank are so highly impregnated with salts that the ridge if

saturated would almost certainly be breached by any water impounded behind it.

The tank formed by impounding the waters of the Wundwin Chaung would be bordered on the east by the dam and the low sandy ridge, and on the north, west and south by gradually rising ground. The greater part of the floor of the tank is composed of alluvium which is thin and sandy in places especially near the dam line.

In Mr. Leicester's opinion the site is unfavourable geologically and he strongly recommends its abandonment. He details the precautions which would have to be taken if the project were persisted in; from them it is clear that the scheme would be a highly expensive one.

Siruvani Dam Site, Coimbatore District, Madras.

Two visits were paid to the Siruvani Dam site in Coimbatore by Mr. Vinayak Rao, and samples of the soil were sent to the Geological Survey Laboratory for porosity tests. The dam site appears to Mr. Rao to be sound enough to support a high dam. The porosity tests were satisfactory, giving a high percentage of pore space, showing that the soil is likely to retain water. In order to bring the water from the proposed reservoir at a height of about 2,750 feet to Coimbatore town, which is at a distance of about 25 miles, a tunnel has been planned of a total length of 4,800 feet of which about 300 feet have been bored through at the eastern end where there is solid rock. Since much of the remaining 4,500 feet would pass through soft soil and decomposed rock, the process would be a costly one and would take a long time to complete. Mr. Vinayak Rao is of opinion that for the supply of water to Coimbatore town it would be better to abandon the present site and to construct a small dam on the Bhawani river near Mettupalaiyam, a distance of about 22 miles from Coimbatore. The pipe-line, which has already been laid down, could be diverted for this purpose. An alternative suggested is the damming of one of the smaller tributaries of the Noyal; for this the pipe-line already laid down could be utilized.

Metur Dam, Coimbatore, Madras.

A visit was paid to the Metur Dam site by Mr. Vinayak Rao, as the Engineers reported that an artesian spring and some joints in the rocks had been found on the site. Metur consists mostly of charnockites with thin bands of older and newer gneisses occur-

ring in an irregular manner. The charnockites are jointed, and as these joints extend some distance below the surface, the rocks had been blasted to a considerable depth. Mr. Rao came to the conclusion that the blasting of sound rock in order to follow the joints or pot holes to the depths to which they extend was unnecessary. He suggests that the joints could be made water-tight by pouring in concrete and by grouting wherever necessary. As regards the artesian spring, it appeared to be the result of the flow of river water from some distance higher up along one of the horizontal joints. As this occurs several feet below the level of the foundations, Mr. Rao considers there is no cause for anxiety, but suggests that bore-holes should be put down on all sides of the artesian spring to test whether similar conditions obtain in other directions.

Dam-sites on the Punjab rivers.

The question of locating sites for storage dams to meet the increasing demands of irrigation in the Punjab recurs yearly. An Irrigation Committee was recently chosen for the purpose of making an examination of the storage resources of the Punjab rivers in the Himalayan foot-hills, between the Jumna and the Chenab. Dr. C. S. Fox was deputed as a member of this Committee, the other members of which consisted of Mr. H. Nicholson, C.I.E., Superintending Engineer, Punjab Irrigation, Mr. A. J. Wiley, Adviser on Dams to the United States Bureau of Reclamation, and Mr. E. S. Pinfold, Chief Geologist to the Indo-Burma Petroleum Company. Visits were made between the 21st November and the 22nd December, 1927 to all the more probable sites for large storage dams. In Dr. Fox's report on the geological aspects of the enquiry mention is made of no less than 33 sites for large dams which have been carefully considered. The most important of these sites is that of the Bhakra gorge on the Sutlej, where this river makes a hair-pin bend before its débouché from the sub-Himalayan range, It has been calculated that a dam built in this gorge, if 500 feet high, would be capable of impounding water in a reservoir which, once filled, would be enough to maintain a flow equivalent to that of the Thames at Teddington for two years.

The enquiry was guided by the following essential considerations :—

(1) that the impounded waters are required for irrigation purposes in the plains some distance away;

(2) that large storage reservoirs are more suitable than small ones of equal efficiency;

(3) that accessibility to the site of a dam is an important factor; and

(4) that favourable geological structure, abundance of building material, and a deep, narrow gorge are most attractive considerations.

Taken as whole, high dams of equal height on mountain rivers have to be longer the nearer they are situated to the plains, but they hold up far larger volumes of water than those higher upstream. With these points in view, the Bhakra site on the Sutlej was considered to be superior to any other site seen. The Balehu site on the Beas was given second place.

Among the sites visited were the following of which details are given in Dr. Fox's voluminous report:—

Markanda River—sites at Ambwala and Moginand, and at Nimbwala on the Sallani, a tributary of the Markanda.

Koshalia River—sites below Koti, Dehli and Banog on the road to Simla.

Western Ghaggar River—Junpur and Baroa sites. A limestone occurrence at Junpur was examined.

Eastern Ghaggar River—Runga, Karta, Chaplana and Bhalog sites. The Morni lakes were examined.

Sutlej River—Bhakra site. An exploration for material was also made.

Chakki Khad—sites at Marel and Lihora.

Ravi River—various possible sites about Thain.

Beas River and tributaries—Balehu and Daroli sites on the Beas, Chatra and Haripur sites on the Banganga, Dhawala site on the Nakehr, Spel and Hariyan (Dehar river) sites on the Gaj.

Ujh River—Mota and Barbari sites on the Ujh river.

Basanter River—Sehwa and Jatah sites.

Eastern Tawi River—Dursuh, Kern, Doa and Bhairgiran sites.

In all these cases the location or site of the possible dam was on Tertiary rocks—usually on Siwalik beds, but sometimes on the older Kasauli, Dagshai and Sabathu strata (or their equivalents, the Murree and Kuldana beds). In most cases the sandstones were thought capable of bearing the weight of a great dam and the

interbedded red clays to be a satisfactory and safe impervious bed. In almost all cases the strike of the strata was across the stream and parallel to the length of the projected dams. In the most satisfactory cases the dip of the strata was steeply down-stream and therefore parallel to the direction of the thrust due to the resultant forces acting on the dam foundations. The question of suitable building material required close attention, as good stone was not available in most of the localities. However, the abundant boulder, pebble and finer material was considered excellent from the point of view of concrete dams, which was the type advocated. The supply of limestone for cement-making was solved by the discovery of valuable limestone near Junpur on the Ghaggar river; this is a new locality and within easy reach of Chandigarh, 10 miles away, on the railway line between Kalka and Ambala.

In all cases, the sites of the dams lie in a seismic region, and the danger from earthquake shock was fully considered. It was thought that the danger from such a cause would be less in the case of short dams in narrow gorges.

The danger from earthquake is a question which was dealt with by the writer of this General Report when advising regarding the Mandi Hydro-electric scheme. Every constructional or building scheme in the Punjab, and more especially in the northern half of the province, must face this danger. It must be remembered, however, that the damage done by earthquakes is comparatively small when due allowance has been made for the usually long periods of quiescence between cataclysms of this kind. To magnify such a danger beyond its true proportions would be to stifle or restrict all progress and development in a province like the Punjab. The prospect of an earthquake must of course be borne in mind when initiating any engineering project in the Punjab, but an additional and more comprehensive safeguard would be the establishment of an earthquake insurance fund in the budget of the Province.

Landslip, Chamba, Punjab.

Dr. C. S. Fox was deputed to examine a landslip which had occurred at Chamba in the Ravi valley. The town of Chamba, which was reached *viâ* Pathankot and Dalhousie, is situated on the right bank of the Ravi on an alluvial terrace 300 feet above the river. The Ravi makes two sharp bends at Chamba, and as a result of scouring at the base of the steep slope at the lower bend the stability of the

cliff face has been affected. Dr. Fox has advised in detail the training methods to be adopted to reduce and finally to prevent the scour at the base of the terrace slope. He has advocated the gradual construction of a pebble and boulder levee which will function as a storm-beach when the Ravi is in spate.

Gas.

Lower Chindwin District, Burma.

A seepage of inflammable gas was found by Mr. B. B. Gupta, about 2½ miles west-south-west of Yeyin (22° 27¼'; 94° 40') in the bed of Thingan Chaung.

Gas seepages were also noticed close to the point where the Sadan Chaung meets the Patolon Chaung in Sheet No. 84-J/11, and in a tributary of the Mankadon Chaung (Sheet No. 84-J/10), at a spot about 2¼ miles, south-east of Kunbyinye Sakan. From one of the numerous seepages of the latter locality small quantities of mud and oil are also exuded and there is an oil seepage close by (see *Petroleum*).

Glass Sand (see Sand).

Gold.

Lower Chindwin District, Burma.

A reference to the minor industry in gold-washing which is carried on in some of the rivers of the Lower Chindwin district in Burma, appears in the General Report for 1927 (Records, Vol. LXI, p. 56). In addition to the localities mentioned there, Mr. B. B. Gupta reports the following additional ones, met with by him during the present season :—

Hlaing Chaung, a tributary of the Yama Chaung. Sheet No. 84-J/12.

Thanbo Chaung, a tributary of the Yewa Chaung. Sheet No. 84-J/11.

Thanbo Chaung, a tributary of the Hmyaing Chaung. Sheet No. 84-J/10.

Gold is also stated to occur in the Thingandon Chaung and in the Hmyaing itself (Sheet No. 84-J/10). Mr. Gupta was unable to

obtain any statistics of production but as far as he could gather the gold is not found in any appreciable quantities in these places.

Mr. V. P. Sondhi reports that gold is washed from Irrawadian sands in the upper reaches of the Siekho Chaung near Taukkyangon (22° 40′; 94° 47′) and from the Imbyaung Chaung at Sedaw village (22° 44′; 94° 59′)—Sheet 84-J/14. The industry flourished in former times when labour was cheap but it is declining rapidly and is now limited to periods of heavy rain, when four to six annas worth of gold can be collected per man per day.

Myitkyina District, Burma.

Alluvial gold is obtained from the sands of the Uru river between Pantin (opposite the confluence of the Uru and the Mawmoan Chaung) and Mamon (25° 35′ 10″; 96° 15′ 57″). The important localities where gold-washing is practised, according to Dr. Chhibber, are as follows:—

An-ma (5 furlongs east of Hpakan, 25° 36′ 38″; 96° 18′ 40″).
Parpyin (25° 35′ 21″; 96° 16′ 40″).
Mamon (25° 35′ 10″; 96° 15′ 57″).
Namsabein, near Haungpa (25° 30′; 96° 6′ 15″).

The fine sand from the lower beds of the Uru Boulder Conglomerate is washed by Shan women who can collect as a rule 6 to 7 annas worth of gold in a morning's work. During 1914-15, an attempt was made by a Mr. Baldwin to win alluvial gold on a commercial scale at Mamon; about 100 oz., together with some platinum, are reported to have been obtained before the experiment was abandoned.

Gold-washing is also carried on during the rainy season near the deserted village of Manna (25° 36′ 43″; 96° 16′ 15″).

Graphite.

Kashmir.

A small quantity of graphite occurs south-east of Reshian in the Uri *tehsil* of Kashmir, in connection with the metamorphosed carbonaceous slate and phyllite belonging to the Salkhala Slate series. Mr. Wadia reports that the quantity seems to increase steadily to the S. & S. E.; six miles N. of Uri, the graphite-bearing band is greatly enriched and is about 20 feet thick. Large graphite and ochre deposits have been observed by Mr. Middlemiss to the east and south-east of these localities.

Iron.

Myitkyina District, Burma.

Three large occurrences of iron ore are reported from the Myitkyina district by Dr. H. L. Chhibber. The village of Lamong (35° 37′ 36″; 96° 15′ 17″) is situated on the northernmost outcrop. The second one lies about 1¾ miles, south-south-east of the same place; its outcrop is 1½ miles long and about one furlong broad. The third and largest is exposed on the Mamon-Haungpa road; the ore is seen first about a mile west of Nammaw (25° 38′ 20″; 96° 15′) and continues intermittently for about 6 miles, to nearly a mile west of Kattang village (25° 31′ 2″; 96° 10′ 36″).

The ore generally occurs in the form of boulders scattered through a rich red earth, but in places forms a hard crust entirely devoid of vegetation. Earthy and crystalline hæmatite and limonite make up the great bulk of the material. Dr. A. W. G. Bleeck, who mentioned these deposits in 1908, regards them as "formed by precipitation from aqueous solution," and terms them bog iron ores or lake ores.[1] Dr. Chhibber alludes to them as of residual origin and formed by processes not unlike lateritisation. He states that ferruginous red soil forms a thick mantle everywhere on the peridotites and serpentines of the Jade Mines region and thinks that the iron ores are a further concentration of the iron contents on the surface through the action of capillarity. The local association of the iron ores with the ultra-basic rocks is remarkable and the former occur only in association with the latter. Every gradation between the two was observed, both in the field and laboratory.

The occurrences are found at over 2,000 feet above sea level and generally occupy the tops of plateaux, in certain cases carved out into ridges by erosion. As boulders of the ore are included in the Uru conglomerates, their formation was in progress in late Tertiary times and is still proceeding.

Madras.

Magnetite was found by Mr. Vinayak Rao south of Tatchur on the low hills near the river; the rocks of this locality were referred to the Charnockite series.

[1] A. W. G. Bleeck. "Jadeite in the Kachin Hills," *Rec. Geol. Surv. Ind.*, Vol. XXXVI, pp. 258 and 262 (1908).

Mewar (Udaipur) State, Rajputana.

Two miles north of Thana (24° 13′ : 73° 52′) in Mewar (Udaipur), in the green hornblendic schists (altered tuffs) at the base of the Aravallis, and also in the quartzites adjoining them, higher in the section, there is a great development of hæmatite schist, probably a metasomatic replacement, by hæmatite, of the silica of the green schists and the quartzite. The ore-body, Dr. Heron states, forms a steep and prominent ridge about half-a-mile long, culminating in hill "1895" and showing clear dip slopes to the south-west. No excavations were found, but there are extensive heaps of slag on the east bank of the stream, 1½ miles north-west of Thana, and at other localities near, and all the ore utilized in the old smelting industry may have been collected from the great accumulation of fallen blocks below the ridge.

Jadeite.

Dr. H. L. Chhibber has made a systematic study of the geology of the Jade Mines region and of the local industry. He reports that the largest outcrop of the jadeite-albite dyke is at Tawmaw (25° 41′ 13″; 96° 15′ 28″) and that its proved outcrop is over 300 yards long and 200 yards wide. The dyke is very irregular in thickness and trends generally from north-east to south-west with local variations.

A general section at Tawmaw exhibits :—

(*a*) Thick red soil, from the weathering of the serpentine country rock.
(*b*) Serpentine.
(*c*) Earthy, light green chlorite schist (*byindon*).
(*d*) Siliceous chert or schistose serpentine.
(*e*) Amphibole schist (*shin*).
(*f*) Banded amphibole-albite rock.
(*g*) Albite.
(*h*) Jadeite.

The rocks in the footwall are seldom visible. The thickness of the jadeite and albite vary in direct proportion. Three new outcrops of jadeite are recorded, one at Saramaw (25° 41′ 13″, 96° 15′ 28″) about a mile south-west of Tawmaw, a second at Malin-ka-maw, about two miles north-east of Tawmaw, and a third at Sanhka Hka, about 2¾ miles north-east of Tawmaw. They are all

marked by deserted workings and lie on the N.E.-S.W. line of the Tawmaw strike. Thus the dyke probably extends for at least four miles.

There are two outcrop mines at Tawmaw, the Dwingyi and the Kadon, but the latter has not been worked for the past two years. Operations are only carried on from March to May after which the workings are flooded. The mining industry is gradually declining as increasing depths are reached and the primitive Chinese methods, described in detail in Dr. Chhibber's report, fail. The unsettled political situation in China, to which most of the jadeite is exported, may also be partially responsible for this condition.

There are two localities in the neighbourhood of Tawmaw which have been worked for jadeite boulders of detrital origin in the past. These are known as Pandin-maw (25° 41′ 17″; 96° 16′ 23″) and Paim ma-chait (25° 38′ 51″; 96° 15′).

The numerous workings in the Uru boulder conglomerate are subdivided by Dr. Chhibber as follows :—

(1) Workings in stream-beds.
(2) Workings on hill-sides.

In the latter quarrying is generally done during the Rains, as at Balahka (25° 37′ 30″; 97° 17′ 1″) Manna (25° 36′ 43″; 96° 16′ 15″) and Nammaw (25° 38′ 20″; 96° 15′).

The stream-bed workings commence near Kansi (25° 46′ 54″; 96° 22′ 47″) and continue at intervals to Haungpa (25° 30′; 96° 6′ 15″). In the area examined during the course of his survey Dr. Chhibber found 28 localities where active operations in search of jadeite boulders were in progress between these two places. He has described the mining methods adopted and made various suggestions for their improvement.

Jadeite workings are carried on in Tertiary rocks in the Hwehka neighbourhood and about 20 localities in active operation have been recorded from the vicinity of Kadonyat (25° 15′ 20″; 96° 15′ 46″), Hwehka (25° 29′ 3″; 96° 16′ 43″) Hpaokang (25° 29′ 40″; 96° 16′ 4″) Makapin (25° 28′ 53″; 96° 18′ 4″) and Mawkalon (25° 29′ 55″; 96° 18′).

The mining system followed locally has been described and various useful recommendations made.

Occasionally workings for jadeite are situated actually in the bed of the Uru Chaung, the stream being diverted to permit of excava-

tions in its bed. In the deeper pools diving is resorted to by the Shans in their efforts to obtain the valuable stone.

With regard to the source of the jadeite found in the Tertiary conglomerates of Hwehka, Dr. Chhibber concludes that the stone cannot possibly have come from the Tawmaw dyke and that there must have been another primary occurrence of the mineral associated with the peridotites and serpentines of the south, which has either been denuded away or is still concealed in the impenetrable jungle.

Lead.

Central Provinces.

A sample of pyromorphite was forwarded to the Department for identification. It is reported to have come from one of the Feudatory States of the Central Provinces but further details are not forthcoming.

Limestone and Dolomite (See also Building Material).

Gangpur State : Bihar and Orissa.

Limestone and dolomite form by far the most important deposits of economic value in Gangpur State. There are two series of outcrops, one on the north and the other on the south side of the anticlinorium mapped by Dr. Krishnan (*see* page 97). In the southern belt these beds are being worked at Ursu (22° 17′ 30″; 85° 1′), Khatangkudar (22° 17′; 84° 59′ 30″), Bangurkela (22° 16′ 30″; 84° 57′ 30″), Jagdah (22 16′; 84°55′), Banposh 22 15′, 84°48′), Beldih (22° 15′; 84° 45′), Usra (22° 14′ 30″; 84° 12′), Amghat (22° 15′; 84° 37′ 30″). In the northern belt where the most important workings lie, the producing quarries are all in the neighbourhood of Raipura (22° 24′ : 84° 44′). The quarries are leased to various concessionaires, of whom the principal are the Bisra Stone and Lime Company, Tata Iron and Steel Company, and Messrs. Byramjee Pestonjee & Company. A certain proportion of the limestone is burnt for lime, but by far the larger proportion of the stone extracted is sent to the smelting works of the Tata Iron and Steel Company, the Indian Iron and Steel Company, and the Bengal Iron Company for use as flux in the manufacture of pig iron. Formerly dolomite was used in large quantities, but the smelting companies now prefer limestone and there has consequently been a great falling off in the despatches of dolomite and an increase in the despatches of limestone.

Myitkyina District, Burma.

Limestone, in places metamorphosed to marble, forms small outcrops in the Jade mines region of Upper Burma, and is burnt for lime around Kamaing

Manganese.

Gangpur State : Bihar and Orissa.

Dr. Krishnan visited three small openings for manganese-ore at Gobira (22° 18′ 30″): 84° 43′ 30″), Ratakhand (22° 19′ : 84° 42′) and Andharitoli (22° 21′ : 84° 34′) which were worked for manganese-ore during and immediately after the War. Owing to the low grade of the ores, which are pyrolusite and psilomelane, production ceased as soon as prices fell. All three occurrences have been identified as of the gonditic type.

Kanara and Belgaum districts, Bombay.

The manganese occurrences of some of the forest areas in Kanara and Belgaum districts were mapped by Mr. Vinayak Rao with the assistance of Sub-Assistant A. K. Dey. The ore is found mostly in the laterite, capping the hills and on some of the hill slopes as mentioned in previous reports. In addition to the modes of occurrence noted already, manganese is found below hæmatite in some of the laterites. When therefore any iron ore is seen on top of the laterite, a search may reveal manganese below.

The Dharwars consisting of quartzites, phyllites and limestones with mica schists are found extending from the Khanapur *taluq* in the Belgaum district in a southerly direction into the Kanara district, where they can be traced as far as Gokarn. A trace of manganese was found in the laterite as far south as Yellapur. Where the gneisses form low hills with laterite on the top and a thin band of Deccan trap below, manganese is not found. The principal occurrences of ore are in the following places :—

(1) On the way round Talewadi to Krishnapur.

(2) Below Bhimgad Fort between Anmod and Karambal on the Portuguese Frontier.

(3) On the slopes of Darsan Gudda or Darsan Dongan at heights of 2,750 and 3,000 feet.

(4) Near Villia village between Ninnor (15° 19′ ; 74° 27′) and Kevarla.

(5) Between Ivoli (15° 21′ : 74° 24′) and Castle Rock (15° 24′ ; 74° 23′) and near Kuvesi (15° 19′ ; 74° 23′).

(6) South of Jamgaon—with manganese at three different levels.
(7) Between Nerse and Kavale at an elevation of about 50 feet opposite to the village Dhangarwada.
(8) East of Puseli village.
(9) Between Jagalbet (15° 20′ ; 74° 33′) and Supa (15° 16′ ; 74° 33′), on top of the hill close to the road, near mile "44."
(10) West of Kasarla (15° 22′ ; 74° 29′) between Ninnor and Ivoli.

The limestones in the Dharwars are contorted and appear to occupy the highest position in the whole series. Granite and gneiss are usually found on low ground, though in Darsan Gudda they occur at a height of nearly 2,500 feet. The Dharwars near the Deccan trap are very much hardened and do not appear to have any manganese contents. Hæmatites are found on the hill south-east of Supa and traces of iron ore are found in the laterites elsewhere. Though the laterite is found extensively developed in this area it is only in places where it overlies the Dharwar quartzites that it appears to be rich in manganese. In Boyce's concession near Jamgaon manganese is found at three different levels. In places it is completely masked by overlying soil below which occurs a lilac-coloured laterite. Mr. Vinayak Rao remarks that the above is not an exhaustive list of manganese occurrences; south of the Kuvesi area, however, granites are found occupying both the hills and the plains so that there is no chance of finding manganese in that part of the country. In places where the Dharwars alone occur no traces of manganese were found. In the Shiroli (15° 7′ ; 74° 39′) area lenticular occurrences of the ore were found beneath a thin capping of laterite.

Ochre.

Uri tehsil ; Kashmir.

Associated with the graphite of Reshian in the Uri *tehsil* of Kashmir are fair-sized pockets, 2-4 feet in diameter, of fine, yellow, brown, and umber ochre, the residue of nests of pyrites enclosed in the Salkhala Slates. The quantity of ochre, as in the case with the graphite, increases south-eastwards, where the deposits, in Mr. Wadia's opinion, occur on a scale capable of industrial development. Numerous chalybeate springs and brooks near Reshian deposit a considerable quantity of ochreous silt on their beds to-day. To the E.

and S.E. of these localities, Mr. Middlemiss has observed large graphite and ochre deposits.

Madras.

North of Tatchur in the Arni Jaghir Mr. Vinayak Rao found a red earth capping the high ground. It is used locally for colour-washing houses.

Oil Shale.

Salt Range, Punjab.

A low-grade oil shale was noted by Dr. Cotter, associated with the salt marl in the Punjab Salt Range. The shale, which emits the characteristic smell on burning, is sharply folded into miniature anticlines and synclines. Dr. Cotter observed none which he considered of commercial importance.

Petroleum.

Lower Chindwin District.

The oil seepages which occur in the Pondaung Sandstones close to their faulted boundary with the Irrawadian, in the neighbourhood of Nyaungbinle (Lat. 22° 20′; Long. 94° 39′ 30″), were noticed in the General Report for 1927. (Records, Vol. LXI, pp. 66-67.). Numerous additional seepages have been found further to the north by Mr. B. B. Gupta during the present season which, with one exception in rocks of the Yaw stage, are all in Pondaung Sandstones of Upper Eocene age.

A list of the seepages of this region was given by Sir Edwin Pascoe in 1912[1] and to them the following may now be added:—

(1) 1½ miles west of Yagyi, (Lat. 22° 28′; Long. 94° 40′).

(2) 2¼ miles south-east of Kubinye Sakan, in a tributary of the Mankadon Chaung, and close to the mud vents mentioned by Sir Edwin Pascoe under his locality (2).

(3) In the Tongaung Chaung, ¾ of a mile north-east of the Forest rest-house; this seepage is dry at present.

(4) Near the source of the southern branch of the Yenan Chaung, in Yaw shales.

(5) In the Thayet Chaung, close to a site which is being drilled by the Burmah Oil Co. Ltd., two miles west of Kongyi, (Lat. 22° 41′; Long. 94° 40′ 25″).

Unsuccessful drilling tests have been made by three companies in past years in various parts of this region. The seepages bear

[1] "The Oil Fields of Burma," *Mem. Geol. Surv. Ind.*, Vol. XL, Pt. 1, pp. 144-145.

witness to the presence of oil; according to Mr. Gupta, with the exception of one or two, they are all on the western arm of the anticlinal fold, away from the crest. He also observes that suitable rocks capable of acting as oil reservoirs are rare while the nature of the local strata render drilling operations unusually difficult.

Platinum.

Myitkyina District, Burma.

Small quantities of platinum, according to Dr. H. L. Chhibber, occur, with alluvial gold at the various localities mentioned by him in the valley of the Uru River (see *Gold*). He doubts whether the local inhabitants realise the value of the metal for, after picking out the gold, the rest of the concentrate is thrown away.

Pyrite.

Myitkyina District, Burma.

Iron pyrites occurs in perfect cubic crystals—the largest of which are over one inch in diameter—in the crystalline schists at Kadonyat (Lat. 25° 3′ 20″: Long. 96° 15′ 46″) in the Jade Mines region of Upper Burma.

North Arcot District, Madras.

Signs of iron pyrites were noticed by Mr. Vinayak Rao in the low hills, 1¼ miles south of Kaniyambadi village, east of the road in the North Arcot district of Madras. Some pits were put down by Field Collector A. K. Dey but the veins were narrow and the occurrence does not appear to be of economic importance.

Traces of iron pyrites were found in the hill west of the road at the 9th mile on the Vellore-Arni road.

Salt.

Sagaing and Shwebo Districts, Upper Burma.

During the course of his survey of Sheet 84-N/16, Mr. E. J. Bradshaw visited several salt-fields which are actively exploited by the local inhabitants. Salt-fields exist at the following localities, of which Minbo and Tagalet are not shown on the map :—

Sadaung	(22° 9′ 34″; 95° 45′ 28″)
Minbo	(27° 7′ 1″; 95° 52′ 10″)
Baukthauk	(22° 8′ 26″; 95° 50′ 23″)
Kongyi	(22° 8′ 47″; 95° 50′ 31″)
Tagalet	(22° 14′ 53″; 95° 49′ 9″)

With minor differences in detail the method of winning the salt is the same in all the fields, and that used at the Tagalet field is described below.

Wells about 3 feet in diameter are dug to a depth of from 30 to 35 feet and revetted or lagged with wicker-work or bamboo matting. The brine is raised by hand in an earthern pot by means of a rope passing over a pully. On reaching the surface the brine passes along a trough of dug-out tree trunks into a shallow circular pond, from 12 to 15 feet in diameter, formed by a low, clay ring-dyke about 1 foot in height.

Here the brine is left for some time to concentrate in the sun and is then scattered by hand over sandy soil, raked by hand or with the aid of buffaloes. When the water has evaporated the sand is harrowed either with large wooden rakes or by harrows drawn by buffaloes.

The salty sand is then dumped into filters which are cylindrical hollow heaps of sandy clay from 4 to 5 feet in height, stiffened with bamboo struts or straw and basket work and with a hollow bamboo serving as an outlet near the base. Brine from the pond is poured over the salty sand in the filter and, percolating through, is both enriched and filtered.

At frequent intervals the salty sand is removed and thrown back on the ground where it is raked and re-charged, thus completing the cycle. In some cases efflorescent sand, "*sapaya*," naturally rich in salt, is transported from a distance and mixed with the salty sand in the filters. At Tagalet, for instance, about one-third by bulk of imported soap-sand is mixed with two-thirds of the local artificially enriched sand.

The concentrated brine from the filters is placed in shallow, rectangular, tin pans about 1 foot by 2 feet 6 inches and evaporated to dryness over a wood fire in a clay oven. During the process of evaporation the brine is kept stirred by a ladle ingeniously fashioned out of ordinary enamel plate with a wooden handle attached.

The salt is clean and white in appearance and seems to be of good quality. Where bullocks are used in harrowing, the salt is less pure, and in the case of some fields the natural brine is dirty and discoloured.

At Tagalet there are ten wells, at Kongyi six, at Baukthauk four, and at Minbo seven. The number of wells at Sadaung is not known.

The duty levied is 6 annas 1 pie per *maund* in the case of evaporating vessels licensed at Rs. 30 and 4 annas in the case of vessels paying Rs. 20. At Tagalet the total daily output averages about 150 *viss* of salt. The capacity is about 250 *viss* but there is insufficient wood fuel available. Mr. Bradshaw was told that the average life of a well was about 15 years and that the average annual cost of fire-wood per well was about Rs. 70. During the Rains work has to be curtailed, at Tagalet for 4 months it is suspended for 3 or 4 days each month on an average. Kongyi and Baukthauk fields are said to be shut down for three months in the year and Minbo for eight months owing to flooding from Kadu Lake. The salt is all sold locally. The price at Tagalet is Rs. 1½ per 10 *viss*. The salt is carried away in bullock carts on bamboo matting thinly coated with *ghee* to prevent the salt shaking through. In the villages the salt is sold at As. 4 per *viss*. A cart-load equals 200 *viss* whose cost at the field is Rs. 30 and price in the village is Rs. 50 thus ensuring a substantial nett profit to a retailer after the very low cost of transport has been deducted.

The industry, however, provides very small profits for the actual well-owners. Assuming that the Tagalet field, probably the most remunerative, maintained a daily output of 150 *viss* throughout the year, its value at Rs. 1½ per 10 *viss* would be about Rs. 8,200 a year. The cost of fuel and tax for 10 wells amount to, say, Rs. 1,000 a year, leaving Rs. 7,200 to pay for labour, or a monthly wage bill of Rs. 600. About 30 to 40 people are employed in the field but these are usually entire families. Assuming that they were equivalent to 30 ordinary coolies the annual turnover would only ensure a monthly wage of Rs. 20 to each. It has also to be remembered that no provision has been made for the cost of sinking wells or for the fact that the daily output is not continuous throughout the year. The industry at present provides only a bare living wage for the well-owners. Mr. Bradshaw is of opinion that none-the-less it merits encouragement and that with careful supervision and the introduction of more modern methods of working and, in particular, of purifying the salt, it might be capable of development and expansion.

Mr. Bradshaw thinks that the source of the brine lies in the concretionary zone at the base of a finge-rained, friable, greenish, micaceous, Pegu sandstone, the salt having collected there probably as a result of the percolation of overhead waters. He notes that

the water from springs or wells at this horizon is invariably salt while that from higher horizons is sweet.

Salt Range, Punjab.

An examination of the following areas, at the request of the Commissioner, Northern India Salt Revenue Department, with a view to the future exploitation of rock-salt, was carried out by Mr. Gee.

1. The Jutana-Chanuwala area.
2. The Makrach area.

About ¾ mile up the Kathi Kas to the east-north-east of Jutana (32° 43′ : 73° 9′ 30″) the basal beds of the Purple Sandstone series crop out, and the uppermost gypsiferous strata of the Salt Marl group are exposed. Among previous records the existence of an old salt mine in this locality is mentioned, but since some considerable time no salt has been excavated in this area. The water in the lower courses of the stream is slightly saline, and rock-salt would doubtless be met with in the marl beneath the Purple Sandstone group. The strata dip into the hill sides on either side at a fairly steep angle—from 40° to 45°—decreasing considerably to the north and south. The structure, especially on the north side of the gorge suggests a large area of salt marl, relatively undisturbed, underlying the higher groups of strata. The cost of proving this area would, however, be considerable, necessitating a number of deep borings sited on the gently sloping ground above the gorge, or several adits which would doubtless have to pass through an unknown thickness of marl before a workable seam of rock-salt was met with. During the driving of these drifts and the working of the deposits the possibility of flooding from the water of the stream would have to be guarded against. Since these workings would all be well below the level of the stream-bed in the vicinity, this danger during periods of excess rainfall would be serious.

In the Chanuwala (32° 43′ 30″; 73° 8′) area the foot-hills of the range appear to be composed of the Salt Marl, in which are included irregular masses of gypsum. From superficial evidence the whole of this exposed mass of salt marl appears to be much disturbed and shows no regular stratification. Several outcrops of rock-salt occur. The area resembles that into which the Nurpur Mine of the Nilawahan is excavated. From the mode of occurrence of the rock-salt in this mine together with the surface evidence

which further suggests that the digestion of any seams of rock-salt which may occur under such exposed masses of marl has already taken place to a large extent, it seems probable that within the foothills of the Chanuwala area, large masses of good quality rock-salt which had excaped solution from percolating waters, might be encountered. Such deposits might be found as would allow profitable exploitation, but as in the case of the Nurpur Mine, it would be difficult to define the limits of these deposits, whose existence depends on the chance of their having escaped erosion by water percolating through the marl. Once access to a seam of salt has been gained by percolating solutions, its rapid digestion would immediately be followed by the subsidence of the marl above, and the opening of numerous channels for further percolation. Such circumstances appear to have been largely responsible for the disturbed condition of the exposed marl in the Chanuwala and other areas.

Higher up the stream-courses in this area the Salt Marl, with outcropping seams of rock-salt, is exposed *in situ* beneath the Purple Sandstone group. It is probable that large areas of workable salt exist here, but the question of transport might prevent them from being of present economic importance. Detailed mapping in this locality will no doubt, throw further light on the extent of these deposits.

The precipitous spurs overlooking Makrach (32°40′ ; 72°53′30″) from the north, west and southwest, are comprised of the disturbed purplish red Salt Marl, as noted in the foot-hills of the Chanuwala area. That this marl included deposits of rock-salt is evidenced by the numerous solution holes and recent subsidences which occur over the area. An old mine existed many years ago in the salt contained within the marl just west-north-west of the village. The area, however, which, in Mr. Gee's opinion, is most promising for exploitation is the Chittidand plateau, lying between the main Makrach gorge—running south-west from Makrach village—and the Nawabi Kas, to the west-north-west of the village. The plateau is intersected by a small fault running northwest across the eastern end of the area about 1 mile due west of Makrach village, and a second fault, following a north-north-westerly direction, runs up the tributary (near which Salt *Chauki* No. 29 is situated) about 2 miles west south-west of the village. The structure is a gentle syncline and between these two faults it appears to be undisturbed. That

this is so on the eastern part of the area is proved by the colliery workings of Chittidand Colliery, a through connection having been driven in an approximately north-to-south direction, in the coal-seam which underlies the Nummulitic limestones. Assuming the above-mentioned structure it implies a wide area, well over one square mile in extent, in which the Salt Marl exists in a relatively undisturbed state. There is plenty of evidence of the occurrence of thick seams of rock-salt in the exposures on both the north-eastern and south-eastern scarps of the plateau. The seams crop out well up the slopes so that all danger of flooding from the waters of the stream below is eliminated. The area might be proved either by adits driven into the outcrops on the hillside, or by borings located on the stable Purple Sandstone or higher beds further up the slopes. The distance from Chittidand Colliery, near by, to the Sind Sagar branch of the North-Western Railway, a distance of about 7½ miles, is now traversed by a light railway.

A visit was paid by Mr. Gee to the drifts which are being driven into the salt deposits of the southern slopes of the Jansuk gorge, near Rukhla, with a view to proving the thickness and extent of the rock-salt of that area, previously reported on. Three drifts had been commenced near the sites recommended. The most easterly drift, sited in the lower slopes, had, as was expected, encountered the disturbed, slipped marl for some distance, but had then been abandoned on account of the trouble encountered in supporting the roof. The middle drift had been driven in a southerly direction in rock-salt for a distance of about 190 yards. The western drift, following an east-south-easterly direction had penetrated to a distance of 80 yards through salt and disturbed salt marl. After passing a large solution-hole massive rock-salt had been encountered. These two latter drifts looked promising, and were being continued.

Sand.

Kashmir.

The Infra-Trias limestones in the vicinity of Garhi Habib Ullah and Muzaffarabad are silicified in a peculiar way resulting in the accumulation of large masses of soft, granular, almost powdery silica. The silica is free from iron and is mixed chiefly with the residues of unaltered limestone; as it occurs in scree-slopes, moderate quantities are

available by surface scraping and would, according to Mr. Wadia, be suitable for glass manufacture.

"Soap Sand."

The rocks of Upper Tertiary age in those portions of the Lower Chindwin district surveyed by Mr. V. P. Sondhi are often impregnated with alkaline salts which effloresce on the surface in certain places. These are collected by the local inhabitants and used to launder clothes.

Lower Chindwin District.

About a mile east of Yedwet (Lat. 22° 32′; Long. 95° 11′), water, highly charged with such salts oozes from the ground over a large area and forms a small stream running west. It is not potable and is useless for irrigation but is allowed to spread over a flat tract to evaporate and yield its load of soluble mineral matter.

"*Sapaya*," or soap sand, is of frequent occurrence in the area represented by sheet 84-N/16. Mr. Bradshaw reports that its origin is similar to that of brine in the district (*see* "Salt") and also by evaporation from Kadu Lake which is salt. It is not commercially exploited to any considerable extent. In the Padu area the local inhabitants collect and sell it, especialy in years of poor harvest. During 1926 a little less than 300 tons of soap-sand, value Rs. 2,691 was produced in the whole of the Sagaing district.

Sagaing District, Burma.

Sulphuretted Hydrogen.

Springs charged with hydrogen sulphide were noticed by Mr. B. B. Gupta in the Kunyon-bin Chaung, a tributary of the Satha Chaung and in the Sindon Chaung on Sheet No. 84-J/12 of the Lower Chindwin district.

Lower Chindwin District, Burma.

Tin.

Dr. J. Coggin Brown accompanied the Financial Commissioner (Reserved Subjects) on his visits to the Mergui and Tavoy districts between May 24th, and June 18th, 1928 and has submitted a number of confidential reports on various aspects of tin mining and dredging in those districts.

Mergui and Tavoy Districts, Burma.

Water (see also Engineering Questions).

Government House, Ranchi, Bihar and Orissa.

The Government of Bihar and Orissa having asked for the services of an officer to advise them in regard to an increased supply of water for the new Government House at Ranchi, Mr. Jones was deputed for this work. Mr. Jones considers that, where the rock is mainly a compact gneiss covered by decomposed gneiss and soil, as in this case, it is largely a matter of luck whether any quantity of water will be obtained by sinking a well in such country. However, a point selected by the Engineers in charge of the scheme, seems to hold out possibilities of success. The well in the Radium Institute compound, which is close to the point selected, seems so superior to, and apparently recuperates so much more quickly than, the surrounding wells, that it seems justifiable to deduce that it has been put down on a fault or joint plane. Its recuperative powers should be confirmed in the hot weather. A new well put down in the low ground in a position somewhere along the general direction of one of the lines of jointing in the rock, *i.e.*, S. S. E. from the well in the Radium Institute compound, with drifts running more or less at right angles to this direction, would appear, therefore, to have some chances of being successful.

An alternative and perhaps more advisable method of increasing the supply of water for Government House is the deepening of the existing wells on the race-course; these at present do not give an adequate supply of water during the hot weather. Dr. C. S. Fox reported on the water supply of Ranchi in 1913, and fixed the position of these wells on the race-course, along a line of fault or master jointing which runs through Pahargonda hill. These wells have only been put down 20 and 22 feet respectively, although Dr. Fox recommended that a well at this point should be carried down 40 feet. In speaking of the water supply of Ranchi generally Dr. Fox remarked that if the wells were sunk on an average to depths of 50 and 60 feet instead of the present 30 feet there would be a better supply both in quantity and quality.

The Waterless tracts of Upper Burma.

In August 1926, Dr. J. Coggin Brown undertook to supply such geological information as is available on the problem of obtaining underground water supplies in the waterless tracts of the "Dry Zone of Upper Burma," for domestic and agricultural pur-

poses. The General Report of that year contains a summary of the situtation in the Myingyan district by Mr. C. T. Barber while in the report for 1927 Dr. Coggin Brown's views on the question in the districts of Thayetmyo, Kyaukse and Mandalay are referred to. The waterless tracts of certain other districts are dealt with below.

Lower Chindwin District.

During his survey of Sheets Nos. 84-J/11, and 84-N/2, N/3, N/4 and N/7, Mr. V. P. Sondhi paid special attention to the waterless tracts situated therein. He states that they all lie on either the porous Irrawadian sand-rock or the older alluvium which is of a semi-permeable character and itself overlies the Irrawadian series. This changes its lithological character very rapidly and evidence of the widespread distribution of soluble salts in it is afforded by wells yielding saline water and by efflouresences of alkaline compounds at places far apart. For these reasons Mr. Sondhi cannot confidently recommend tube wells in any particular locality, but he believes that improvements can be made in the methods of extracting the local sources of sweet water and in its storage and distribution. Surface tanks and reservoirs have to be relied on in the cases of the Magyi-ok, Kontha and Zidaw tracts where the water-table is low and the wells have proved saline. Much water is lost from the existing tanks through percolation and evaporation and more care should be exercised in the selection of sites, and in the reduction of exposed water surfaces to a minimum.

In localities such as those occurring in the Okpo and Kuda tracts of the Budalin Township, it is usual to line the wells with undressed boulders of granite or with wooden planks. These leave open interspaces and beyond supporting the excavations, are useless. Impervious linings would probably increase the available supplies. Deepening is not recommended as it is liable to cause the water to become saline. A well, recently sunk in the Segyi tract (Budalin), south of the railway station of the same name, met with an excellent water-bearing horizon at a depth of 75 feet. Yedwet and Sinyan are villages to the west and at a lower level than Segyi; at Yedwet, the well site should be fixed to the west of the village. In the Lemun and Manklet tracts it is anticipated that water should be obtained at comparatively shallow depths.

In the case of Ayadaw, the headquarters of the township of the same name, wells with infiltration galleries, similar to those under

construction at Monywa, are recommended at Letyetkyi, about ¾ mile to the north.

The Thikyingyi (Ayadaw) tract is situated close to the main water parting of the region at elevations of 750-850 feet above sea-level and it is quite uncertain whether tube wells would be successful in the local rocks.

The Tabon tract in the Kani township could probably improve its shortage by deepening its existing wells, for around Mogaung, 2½ miles further south, a good and permanent supply has been obtained at 80 feet below the surface.

Magwe District.

In the Sale Township of the Magwe district there are 37 villages situated north of the Pin Chaung, with a total population of over 10,500 and 6 villages, also north of the same stream, in the Yenangyaung Township, containing at least 5,500 inhabitants, in which the local wells and tanks fail in the dry season. Supplies are then obtained from the Gwebingyo, Segan and Naywedaw tanks wherein water is reported to be abundant throughout the year. They are to be found on Sheets Nos. 84-J/13, L/14, P/1, and P/2, of the one-inch-to-one-mile survey.

The tract of country enclosing these places is bounded by the Pyin-ma Chaung, the Pin Chaung, the Gwegyo-Ngashandaung Hills and the Irrawaddy River on the north, south-east and west respectively. With the exception of a small area at the southern end of the Singu anticline, it is occupied entirely by Irrawadian rocks or by later deposits above them, and the prospects of successful tube wells at most of the localities indicated are according to Dr. Coggin Brown, exceedingly poor. These Irrawadian rocks are probably of considerable thickness, rise rapidly from the River on the west, or from its alluvial embayment south of Sale and attain heights of over 1,000 feet above sea level within 12 miles. Certain villages lie on the alluvium of the Irrawady but they are closer to the Irrawadian outcrops on the east than they are to the River. It might be possible in some of these cases to obtain water supplies by tube wells, but the tests would have to be comparatively deep and it is impossible to guarantee that the quality of the water would be good.

A water well sunk recently by the Burmah Oil Company, Limited, at Pyin-ma through low dipping Irrawadian sandstones, though outside the area under discussion, has a direct bearing on the ques-

tion. This well is 180 feet above the Irrawaddy and 700 feet from it. It has a depth of 410 feet. The 20-inch casing was cemented at 97 feet. Water was encountered at 120 feet and the hole was deepened to 210 feet. The water was of very bad quality with a permanent hardness of over 50 parts per 100,000 with nitrites in addition. The well was then deepened to a hard band at 293 to 297 feet and the 17-inch casing cemented at 297 feet to shut off this undesirable upper water. Drilling was then continued to 410 feet but only insignificant quantities of water were met with; at 410 feet the hole could be easily bailed dry and it was then plugged back and abandoned. It has been found that efflorescent salts occur on the bluffs of Irrawadian sandstone overlooking the river at Pyin-ma, and it seems that the river water, filtering through, dissolves these soluble salts. Though it should normally be pure, therefore, it becomes in this way endowed with a hardness which renders it unfit for domestic purposes.

There are instances, of course, where good water is being obtained from the "water table" on the Irrawaddy but, until tests are actually made, Dr. Coggin Brown finds it impossible to foretell what the results will be, or to advise expenditure on borings in cases like these, unless it is clearly understood that they may result in failure. For the same reason, a really deep test in the centre of the synclinal area which may exist between the Yenangyaung-Singu anticlinal line and the Gwegyo-Ngashandaung one further east, interesting though it would be from a geological point of view, cannot be confidently recommended.

Between the Pin and the Kadaung Chaungs, forming a compact group in the north-west of the Yenangyaung Township there are eight villages with a total population of over 4,700 souls, which suffer from scarcity of water during the dry season. They lie on Sheets 84 P/2 and P/3 of the one-inch survey. Supplies are then obtained from distant tanks or from holes in stream-beds. In no case is the elevation of the village concerned much below 700 feet; in some it is much higher. The local rocks belong to the Irrawadian, covered in places with patches of Plateau Gravel or alluvium. The prospects of good tube-well supplies, as the term is usually understood in Burma, in these situations are practically hopeless.

Lying on the higher Irrawadian rocks, or on the thin surface deposits above them, in Sheet No. 84 P/3, and to the south-east

of Yenangyaung there are eight waterless villages with 4,600 inhabitants. Their prospects of underground water supplies are no better than in the last case.

The Natmauk Township has 13 waterless villages, lying on Sheets 84 P/6 and P/7 of the one-inch survey, with a total population of some 18,500 souls. When the local water supplies become exhausted the people resort to distant tanks and pools left in stream-beds. Four of these villages are situated on the Pegu beds of the Wetchok anticline. Sir Edwin Pascoe, writing on this area in 1908, (*Rec., Geol. Surv. India,* XXXVI, p. 286-294) remarked on the great difficulty of obtaining surface water there. The other villages are on Irrawadian rocks. Generally speaking, the prospects of successful borings are so poor that they cannot be recommended.

In the Magwe Township, north of the Yin Chaung, there are 47 "waterless" villages situated on Sheets 84 L/16, P/3 and P/4, of the one-inch survey, containing at least, 18,000 inhabitants and probably many more. In the dry weather some of these obtain water from distant tanks and others from the Yin Chaung or from the Irrawaddy River. Most of these villages are at high elevations on Irrawadian rocks, in which tube wells of the ordinary type have an exceedingly poor chance of being successful. As numerous villages, especially those lying to the north and north-north-east of Magwe itself, rely on the Irrawaddy River for water when local supplies fail, it is necessary to consider carefully any available data regarding wells drawing supplies from its water table, in spite of the poor results of the Pyin-ma well described above.

A tube well, with a diameter of six inches, was sunk in Magwe in 1923. It yielded good potable water, to the extent of 3,512 gallons per hour from a depth of 102 feet.

Yenangyaung, although it is not within the area under consideration, possesses five tube wells, one of which was drilled in 1915 and the remainder in 1918. The first gave 2,000 gallons and the others 6,000 gallons each per hour from depths varying between 79 and 100 feet below the surface.

These Magwe and Yenangyaung wells may draw their supplies from alluvium but the Nyaunghla well of the Burmah Oil Company penetrates Irrawadian sandstones which dip at 45° to 50° towards the river. It is 4,250 feet from the Irrawaddy and 175 feet above it. Its total depth is 300 feet and the diameter of the first casing is

21 inches. Practically no water was found above 170 feet. At a depth of 185 feet it was found impossible to lower the water level by bailing tests. After further deepening to 300 feet and the introduction of 17-inch casing to 267 feet with 56 feet of perforated 13-inch " liner ", there remained still about 120 feet of water in the hole which all bailing and pumping tests failed to exhaust. It seems, therefore, that in the immediate vicinity of this well there is an apparently an inexhaustible supply of clear fresh water between 180 feet and 300 feet below the surface.

Dr. Coggin Brown notes that the Paungadaw wells of the British Burma Petroleum Company furnish further examples of successful borings through Irrawadian rocks into the water table of the Irrawaddy river. They are both situated close to the river and about two miles west of Twingon, on the Yenangyaung Oil Field. The first well after piercing 80 feet of yellow sands, met water sands between 80 feet and 132 feet. This water was saline and unsuitable either for domestic or engineering purposes. Between 122 and 125 feet a thin band of clay was encountered and a 13-inch pipe was cemented on this. Further drilling revealed sandy shale and stiff clays followed by coarse gravel. A second water sand underlain by clay was penetrated between 162 feet and 186 feet. The water from this second sand is said to be of excellent quality and although the well has never been tested it has yielded up to 9,000 gallons per hour since it has been in use. In the second well the 13-inch casing was cemented at 144 feet, as a good water sand occurred between 144 feet and 272 feet, underlain by a sticky clay between 272 feet and 278 feet and from that depth to 358 feet where the boring was stopped, by a dense sandstone with no water. The well is stated to be a much better one than the first. Although these wells prove that abundant supplies of good water can be obtained from Irrawadian rocks lying within the " water table " of the Irrawaddy River, they do not indicate how far, either to the east or the west the " water table " extends. Whether experimental borings to find this are justifiable, or whether it is feasible to pump water from wells located near the river, to inland villages, are not geological problems and must be settled by the authorities concerned.

To the south of the Yin Chaung there are 35 villages with over 9,000 inhabitants, situated on Sheets 84 M/1, M/5 and P/4 of the one inch survey; these draw their water supplies either from the Yin itself or from the Irrawaddy in times of drought. The

area is occupied by Irrawadian rocks, rising rapidly from the Yin on the north and the Irrawaddy on the west, to a maximum height of over 800 feet above sea level. A broad band of Pegu rocks commences some five miles south of the Yin Chaung and lies between the river and the main Irrawadian exposure, throughout this part of the Magwe township. It is not an area within which tube-well drilling can be recommended. Experiments within the narrow belt of alluvium which borders the Yin Chaung might be successful, but the water so obtained would have to be pumped to considerable heights and distances to reach even the outlying villages of this part of the Magwe township.

In the Myothit township there are 23 affected villages, (lying on Sheets 84 P/3, P/7, P/8 and P/12 with over 12,400 inhabitants), most of which lie on the alluvium of the Taungdwingyi plain, discussed in the next paragraph. Seven villages are separated and form a group on the flanks of a ridge of Irrawadian rocks, dividing the main valley of the Yin from that of its tributary, the Kanthit Chaung. It attains a height of over 900 feet and prolongs, though to a lesser degree, the high ground of the Wetchok-Yedwet anticline in the Pegus. The prospects of successful tube wells about the villages of this group are so meagre that tests cannot be recommended.

The "waterless" villages of the Taungdwingyi township are said to depend, without exception, upon their own tanks for supplies during periods of scarcity; it appears, therefore, that no great distress is really experienced in these cases. Thirty-nine villages, with a total population of 24,750, are enumerated; they are situated on Sheets 85 M/9, M/10, P/8 and P/12 of the one-inch survey. Many of them lie on the alluvium of the Taungdwingyi plain or on the Irrawadian rocks which surround this broad expanse. On the west the Irrawadian outcrop extends for considerable distances but on the east it is soon followed by the chief Pegu outcrops of the Yoma, which rise to a maximum height of 1,600 feet. Taungdwingyi itself is on the alluvium but quite close to the Irrawadian band which intervenes between it and the Pegus. It possesses three tube wells of six inches diameter, sunk in 1917. Two draw their supplies from a gravel band between 79 feet and 89 feet below the surface and the third from a similar layer at 102 feet to 120 feet. They have probably penetrated the alluvium and entered the underlying Irrawadian beds. The initial quantities

of potable water obtained here were 3,000 gallons per hour in the cases of Nos. 1 and 2 and 1,750 gallons per hour in the case of No. 3. Nos. 1 and 2 overflowed at a rate of 2,000 and No. 3 at 88 gallons per hour. Water under true artesian conditions has thus been proved to underlie the Taungdwingyi plain. It is perhaps collected on the high ground of the Pegu Yoma to the east, and being unable to enter the comparatively impervious Pegu rocks flows down along their junction with the Irrawadian rock and is stored in them beneath the alluvium of the plain. Villages which are situated either on the alluvium or on the belt of the Irrawadian strata to the east are therefore in favourable geological locations for tube-well experiments.

Meiktila District.

The Meiktila district possesses waterless tracts in the townships of Meiktila, Mahlaing, Thazi and Wundwin. In the first named township there are six ot these.

The first of them, Leindaw, an area of four or five square miles lies on Sheet 84 P/(9 and 13), on the edge of the alluvium of the Meiktila plain. It contains three villages with a total population of 550 households. The tanks and wells dry up in seasons of poor rainfall. The country around Meiktila, according to Dr. G. de P. Cotter, consists of a succession of folds in the Upper Pegus, the distance between crest and crest being about 5 miles. The beds themselves are abnormal, softer, more arenaceous and generally of more Irrawadian appearance than usual. Near Leindaw the dips are high to the west and tube-well boring for water is not recommended by Dr. Coggin Brown.

The second tract of Kangyoya has an area of four square miles with three villages and a population of at least 170 households. Water conditions are much the same as those in Tract No. 1. It lies to the north-east of Meiktila on alluvium, but it is unsafe to predict whether the latter contains water-bearing horizons or not. The local wells in neighbouring places which contain water throughout the year should be examined, with a view to deepening those in the "dry" area if it is possible to do so, without penetrating the underlying porous sandstones.

Suyittan (No. 3) is an area of three square miles with two villages containing 290 households in the south-west corner of Sheet No. 84 P/(9 and 13). Both villages lie on Upper Pegu rocks at elevations of over 1,000 feet above sea level; they both appear to be near

the crests of compressed anticlinal folds and the prospects of good underground water at reasonable depths are exceedingly meagre.

The Mya tract (No. 4) has an area of five or six square miles in the extreme south-eastern corner of the same sheet, extending on to the adjoining one on the east. There are four villages with 974 households on an alluvial area similar to Tract No. 2 above. Shallow experimental borings might be attempted near the Chaunggauk Chaung, south of Ywe.

Tract (No. 5) is an area of three or four square miles, containing three villages with 545 households. Its centre is five miles south-west of Meiktila. All the villages are on Upper Pegu rocks, but within comparatively short distances of the Mondaing Chaung, the chief feeder of the Meiktila lake. A shallow trial boring might be made in the alluvial embayment to the north-east of Thigon.

The sixth tract of Aunggan contains about four or five square miles and lies to the east of No. 5, just described. It has 332 households. With the exception of a smaller area in the north-western portion, which is on the alluvium bordering the southern end of the Meiktila Lake, and another small portion north of Mondaw, occupied by the alluvium of the Chaunggauk Chaung, the whole of the tract is on Upper Pegu rocks at elevations of over 700 feet. The most promising situation for a trial well is on the alluvium to the west of Thayetkan.

There are six waterless tracts in the Mahlaing township but in all of them existing sources are sufficient in years of favourable rainfall.

No. 1 (Eingyidaw) is a small area of only two or three square miles, with 36 households in the south central part of Sheet 84 O/(11 and 15). According to Mr. E. L. G. Clegg's map it is in the middle of a broad, synclinal belt of Irrawadian rocks which stretches across this sheet from north to south. These rocks are very arenaceous and usually consist of fawn, false-bedded sandstones with lenticles of shale. Grits with quartz pebbles are of rare occurrence. Mr. Clegg has recorded his opinion that "no satisfactory scheme is possible for providing a really adequate water supply from tube wells" on such rocks in general, and the chances of obtaining good water in the particular situations mentioned here are very improbable.

No. 2 (Bankwedaw) practically adjoins No. 1 just described and occupies about 15 square miles with five villages containing 1,300 households. It lies on the continuation of the same Irrawadian

syncline and its potentialities are no better than in the case of the Eingyidaw tract.

Although Tract No. 3 (Panaing), covers an area of only three or four square miles, it contains the important village of Panaing with 1,291 households, Sheet No. 84O/ (12 and 16). In seasons of drought the local wells dry up and supplies are then obtained from wells at Kan-u, at distances varying between one and two miles. Mahlaing itself, Panaing and Kan-u are all situated on a narrow band of Pegu rocks which encircles the Irrawadian series described in Tracts 1 and 2 above. The possibilities of potable water from tube wells in Panaing are not good but the occurrence of perennial supplies in surface wells at Kan-u, leads to the conclusion that this aspect of the question needs further examination on the ground.

The Yondaw tract (No. 4) with an area of about four square miles lies on the same synclinal basin as Nos. 1 & 2, and although the greater part of it is built of rocks belonging to the "Passage Beds," it is really no more promising than they are. It contains three villages with 430 households.

The Sedaw tract (No. 5) has an area of about ten square miles containing three villages with 1,347 households, lying on Sheets 84 O/ (12 and 16) and 84 P/ (9 and 12). Passage Beds occupy the whole area and tube-well prospects are very poor.

The Myin-u-hle tract (No. 6) has an area of about one square mile around Myin-u-hle village with 600 households, in the west central portion of Sheet No. 84 O/ (12 and 16). It is situated on steeply deeping Pegu rocks and boring for water is not recommended.

The Thazi township, Dr. Brown continues, has six waterless tracts but existing supplies are sufficient in years of good rainfall.

Thazi (No. 1) is a small area of one or two square miles around Thazi town (730 households) on Sheet No. 93 D/(1 and 5). The town lies on the eastern edge of a long ridge of Upper Tertiary rocks in which prospects of obtaining potable water by boring are poor enough to be ruled out of consideration. To the east is a band of alluvium seven miles wide reaching across to the foot of the Shan Hills. Around Thazi the alluvial blanket is probably quite thin but further east towards the Samon river there are better chances for a successful tube well.

Hlaingdet (No. 6) has an area of about ten square miles on the same sheet containing three villages with 600 households. As a

whole it is an alluvial area which was specially examined by Mr. C. T. Barber. He found a belt of country passing through Sinbinbauk and Aungtha in which perennial supplies of surface water are obtained from a depth of approximately 15 feet. East and west of this the wells dry in the hot season. It is possible that the alluvial blanket around the affected villages is of considerable thickness and that the existing wells have not penetrated to the deeper horizons where water may have accumulated. A deep trial boring between Pomezagon and the Samon would settle the question. An alternative view is that the alluvium is thin and rests directly on porous Upper Tertiary strata, so that percolation takes place to great depths, together with contamination of the water by the soluble salts which these rocks are known to contain.

Alegan (Tract No. 3) is an area of approximately 15 square miles, on the same sheet, containing five villages with 737 households. The eastern half of the tract is on crystalline rocks and tube wells are out of the question. The remainder lies on the alluvium of the Samon Valley and the underground conditions are probably much the same as those in Tract No. 6. If it is decided to test the latter with a deep boring as already indicated, the results obtained, favourable or otherwise, would have much bearing on the problem in this tract as well.

Ywapale (Tract No. 4) is three or four square miles in extent and lies at the northern end of the Thazi ridge, three miles north of the town and extending out slightly into the Samon plain. It possesses two villages with 346 households. Prospects in Ywapale are very poor. Conditions further out on the alluvium are better but it is perferable to wait until trials have been made in the Samon valley before coming to a decision in this instance.

Nyaunggan (No. 5) is a small area of one or two square miles, seven miles south of Thazi, and possessing no better prospects than the latter. Two villages with 690 households are concerned.

Ywagyi (Tract No. 2) is an area of about eight square miles to the north-west of the Thazi ridge with three villages containing 395 households. It is probable that the alluvium on the west of the Thazi ridge is thinner than that of the Samon valley proper, and until experiments have been made in the latter no comments can be made on possibilities in this particular tract.

The Wundwin township contains nine groups of waterless villages. For geological reasons some of these are classified together.

In every case the water supply is reported to be sufficient in years of favourable rainfall.

Tracts 1, 4 and 5.—Sizwe, Kyaunggon and Gyanlon. These three tracts practically adjoin and form a belt of country stretching for some 17 miles from north to south, from the southern limits of Sheet No. O/(11 and 15) across O/(12 and 16) embracing an area of approximately 50 square miles. The Sizwe tract contains four villages with 1,032 households, Kyaunggon four villages with 352 households and Gyanlon five villages with 861. Mr. E. L. G. Clegg studied the geology of this region in 1924-25 and according to his map all the villages lie on the alluvium which coats the anticlinal ridge, running from Mingontaung in the north to beyond Taungnyo in the south. The advisibility of tube-well borings is doubted but if it is decided to undertake a test, the best situation would, in Dr. Brown's opinion, probably be found near Sinthegwe in Tract No. 4.

Tract No. 2.—Yewe. The Yewe tract embraces an area of about 15 square miles on Sheets 84 O/(11 and 15) and 93 C/(3 and 7). It contains four villages with 611 households. These are further out on the alluvial belt than those of the previously described tract, but as the alluvium is pierced by a prominent exposure of Irrawadian strata, it may only form a skin over the underlying Upper Tertiaries and in that case the water prospects are very poor.

Tracts Nos. 7 and 8.—Tamagon and Tihlaing. Tracts 7 and 8 comprise an area of about 20 square miles, on Sheet No. 93 C/(4 and 8). They contain 9 villages with 1,288 households. Most of the villages are situated on the lower slopes of a ridge of Upper Tertiary rocks which attains elevations of over 600 feet, a short distance to the south of Wundwin. The prospects of successful tube-wells within the area are very doubtful.

The Payasu Tract (No. 3) of 20 square miles, lies mainly on the Samon alluvium, some five miles north of Wundwin. The Thedaw tract (No. 6) of 4 square miles is on both sides of the main railway line from Rangoon to Mandalay, between miles "320" and "323", to the south-east of Wundwin. Together they contain 10 villages with some 1,650 households. The general remarks made already as to the possibilities of obtaining water from the alluvial deposits of the Samon valley apply in this case with equal effect. If it is decided to risk borings in either of these tracts, the farther east they are placed, the better their chances of success should be.

Tract No. 9.—Kaing. The Kaing tract is a small independent tract of two or three square miles lying close to the Samon river on Sheet No. 93 C/(3 and 7). It contains two villages with 285 households. Tube-well borings in the alluvial deposits near the Samon, hereabouts, have a reasonable chance of success.

Minbu District.

The waterless tract of Singaung in the Sagu township occupies an area of approximately 110 square miles, situated on Sheets 84 L/(12 and 16) and I/(9 and 13), and contains the following villages :—(*a*) Yamagan, two miles W.S.W. of Minbu with a total population of 534, situated at a fairly high elevation on the Irrawadian rocks flanking the west of the Minbu anticline, in a position in which tube-well borings cannot be advised. (*b*) Thigon, located on the alluvium of the Sabwet Chaung with a population of over 1,000. More shallow surface wells might be provided here; deeper borings would enter the Irrawadian and are not recommended. (*c*) Mondaing, which with its associated villages contains 2,450 souls, practically adjoins Thigon and reproduces the same geological conditions. (*d*) Maungmagan, a single large village, seven miles S. S. W. of Minbu, with a population of 1,020; it lies on the alluvium of the Sabwet Chaung and the possibilities of shallow-wells within this might be investigated. (*e*) Singaung, about 10 miles W.S.W. of Minbu, with 2,150 inhabitants, is the biggest village in the Sagu Township; it is on the alluvium of the Man Chaung, but the success of a tube well here is quite problematical.

The Pwinbyu township contains one waterless tract which occupies an area of about 50 square miles, on the northern bank of the Man Chaung, in Sheets 84 L/(7 and 11), containing the following villages :—(*a*) Sinlu North, with 400 inhabitants. There is little hope of obtaining a water supply by means of tube-wells from the Irrawadian rocks on which this place is built. (*b*) Sinlu South, with 70 inhabitants. The geological conditions are identical with those of Sinlu North. (*c*) Kyaùnggon with Letyetywa; 400 inhabitants. During the summer months the people have to migrate with their cattle to the Mon Chaung, eight miles away. Situated at comparatively high attitudes on Irrawadian rocks, nothing can be done to alleviate the situation by means of tube-wells. A fourth village Yebokgyi lies within the administrative limits of the Pwinbyu township but geologically it belongs to the Zedaw tract.

In the Salin township there are two waterless areas, the first, known as Zedaw, occupies about 100 square miles, to the south of the Salin Chaung, on Sheets 84 L/(10, 11 and 15). It contains the following villages :—(*a*) Yebokgyi, with 600 inhabitants. It is situated on the alluvium of a small tributary of the Mon, known as the Chaungmagyi Chaung—a narrow alluvial inlet, practically surrounded by Irrawadian rocks. An extension of the existing shallow-well system might tide over the present shortage. (*b*) Kyowun with Tabingon and Ywathangan, containing a total population of 1,900 souls; these are dependent on tanks and wells which undergo the usual dessication in summer. At that time the villagers together with those of (*c*) Letme (population, 280) and (*d*) Tawsein (population, 130) migrate to one of the irrigation canals of the Mon system. All these villages lie on the alluvium which has been mapped between the Mon river and the Irrawaddy, but they are close to its boundary with the Irrawadian rocks on the west and the prospects of successful tube-wells in or near them are very poor. The following villages are in much the same position from a geological point of view :—(*e*) Yonbingan South and East and Maungkawgan total population 420; (*f*) Tamagyaung (450) with Kanchaungywathit (170) and Shwedwindu (250); (*g*) Paungdu (210); (*h*) Pabezu (456) with Shanzu (204), Aladawpyin (256) and Wetthaik (492); (i) Ingyinbintha with Padawgyin (450); (*j*) Thithauktaung (90) with Paukyin (70) and Letpyinsu (60). In the cases of (*g*) and (*h*) the provision of more shallow wells in the alluvium seems to be the best solution of the problem. None of the villages in the list are in locations where tube-well borings could be recommended until every other means of dealing with the shortage had failed.

The second tract has an area of 250 square miles and, with the exception of a small piece to the west of the Salin Chaung, forms a compact block of country to the north and east of that stream, in the extreme northern part of the Minbu district. Like most of the other waterless regions both in Minbu and elsewhere, it is occupied by Irrawadian rocks. It contains the following village groups :—(*a*) Kayingauk with Nyaungbinywa and Magyogon, with a total population of 400 souls, situated on Sheet No. 84 L/6, close to the Pegu-Irrawadian boundary. Both rock groups dip at fairly high angles to the east and the villages are not localities at which tube-well borings can be recommended with any hope of success. (*b*) Sanywa with Didokpin; population 100 souls. These

villages are situated on Irrawadian rocks at elevations between 400 and 500 feet above sea level. Tube-wells are not recommended here. (*c*) Thippandaw, Keba and Taungbo, with their associated villages have a population of about 600. Unless arrangements are made to increase the capacity of the existing tanks, the shortage of water from which these places suffer is likely to continue. (*d*) Daungbo, population 100, lies at the head of a small alluvium-filled valley, surrounded on three sides by Irrawadian rocks. It is doubtful if anything can be done here to improve the present situation by means of tube-wells. (*e*) Shwezanthi and Myenu, population 550, lie in the very narrow alluvial valley of the Myenu Chaung. The possibilities of good underground water at reasonable depths in these villages are exceedingly poor. (*f*) Kyaunggon included with this place are the villages of Kokkogyin and Myothit possessing a total population of 360 souls. A tube-well, sunk between Kyabin and the Irrawaddy river, would probably find water. (*g*) Kyabin with Nebugan and Kokodan, (total population, 460) are all situated on alluvium. A site about one mile east of Nebugan is as promising as any within the area for a tube-well. (*h*) Zibyubin -associated with this place are the villages of Yela, Letpandan and Kadan with a total population of 560 souls. Although all the localities are on alluvium, Zibyubin is alone attractive from a tube-well point of view ; the others are too close to Irrawadian rocks in the west. (i) Sizwe with Nyaungbinhla and Kanswe total population, 550 souls. These villages are all situated on the alluvium of the Irrawaddy valley, and the most promising location for an experimental tube-well is as far to the east of Nyaungbinhla between it and the river, as circumstances will permit.

Pakokku District.

In the Pauk township there are two waterless tracts known as Indein and Didokpin. The first is a large area covering 85 or 90 square miles on Sheets 84 K/10 and K/11, with its centre about 10 miles from the Yaw Chaung, east of Pauk. It contains eight villages with a total population of 1,200 souls. The whole region, with the exception of a narrow strip of some 10 or 12 square miles in the north-west, lies within the expanse of Irrawadian rocks to the north of the Yenangyat anticline. The geological maps made by Dr. G. de P. Cotter in 1907-08 and 1914-15 show that the anticlinal structure persists through the southern part of the tract, while in the northern

one the Irrawadian dip away from the Pegus and lower subdivisions of the Tertiary system to the north. The possibilities of obtaining abundant supplies of drinking water from tube-wells within this high region are very poor and attempts are not advocated. The narrow zone in the north-west lies on Pegus with a general dip to the south or south-west at fairly high angles. A spring near Kanthit may be due to the presence of some water-bearing sandstone in this group and is worth further investigation.

The Didokpin tract has an area of about 12 square miles in Sheet No. 84 K/11, and is in geological continuity with the one just described. It contains three villages with a total population of about 1,000 souls. Shallow tube-wells sunk in the alluvium of the Yaw Chaung, or in the Irrawadian rocks close to it might obtain potable water, but the whole question is very problematical.

The Chit Chaung tract is in the Seikpyu township. It has an area of about 30 square miles, divided into two parts and lying on Sheets 84, K/12 and K/8 north of the main road from Seikpyu to Saw. The southern portion is situated on thick deposits of incoherent Irrawadian rocks, according to the geological map prepared by Rao Bahadur Sethu Rama Rau in 1909-10. Tube-wells cannot be recommended at the single waterless village which this part of the tract contains. The remaining portion has three villages with a total population of 574, located on or near the Chit Chaung. Both divisions of the tract form part of a broad syncline of Irrawadian rocks in the Yaw valley. Deep borings for water have not been attempted in such positions as yet in Burma, particularly those which draw their supplies from rain caught on older and higher ground around. While a boring of such a kind in this region would possess more than a purely academic interest, it is an open question as to whether its expense is justifiable.

The Myaing and Yesagyo townships contain the Kundaw and Kandaw tracts. The former, on Sheets 84 K/14 and O/2, with 13 villages and a total population of over 7,200 souls, has an area of about 50 square miles. It was surveyed by Dr. G. de P. Cotter in 1914-15 and by Mr. C. T. Barber in 1925-26. With the exception of some five square miles lying on Pegu rocks, in the extreme east, it is situated on strata which appear to belong to higher divisions of the Tertiary system and in which incoherent sands and gravels with rare intercalated clays predominate. Tube-well experiments are not recommended.

The more eastern of the two sections into which the Kandaw tract is divided (Sheet No. 84-K/15) has an area of approximately 12 square miles. It contains two villages (with a total population of about 1,100 souls) both situated at high altitudes on Irrawadian rocks positions in which tube-wells are likely to be useless. The other part has two small waterless villages neither of which are shown on the one-inch maps. This area of about 10 square miles is largely an alluvial one and contains other villages which do not apparently suffer from want of water. The solution of the problem lies in the provision of supplies similar to those which are sufficient elsewhere, in the two affected villages, rather than in costly tube-well experiments in an unpromising region.

The large Shinmadaung tract has an area of over 150 square miles embracing the dry uplands of the townships of Yesagyo and Pakokku and extending from a point seven miles north-west of Yesagyo (Sheet No. 84 O/2) in a southerly direction, between the Shinmadaung range and the Chindwin river, to the latitude of Pakokku. It contains 32 villages (18 of which are in the Yesagyo and 14 in the Pakokku township) with a total population of some 16,000 souls. The geology of sheet No. 84 O/2 was studied by Mr. C. T. Barber in 1925-26. Many of the villages in the Yesagyo township are shown by him to lie on Pegu rocks, characterised by a predominance of clays with subordinate soft and false-bedded sandstones; they possess, moreover, high dips varying between N. N. E. and N. E. In such situations the prospects of tube-wells are very poor. The villages of Zidaw and Seywa are in better positions on alluvium and if experiments are undertaken, the sites should be picked as far east as possible, in the direction of the Chindwin. In the Pakokku township most of the villages are situated either well within the belt of Pegu rocks or in worse situations still on the Irrawadian to the west of it. Sodwin is actually surrounded by the alluvial deposits of the Irrawaddy and a tube-well here might be successful.

In the parts of these districts represented on Sheet 84 N/16 considerable difficulty is experienced in obtaining fresh water.

Sagaing and Shwebo Districts.

Lake Kadu covers an average area of 40 to 50 square miles and, having no outlet, its waters are extremely salt and contain an average of 12·4 per cent. of sodium chloride. A tube-well sunk at the Agricultural Department's farm at Padu produced brine only

and, throughout the area covered by the sheet, the water from the majority of the wells is to some extent salt.

Mr. Bradshaw who surveyed the sheet during the present season considers that this salt is derived from the Tertiary rocks and notes that the bulk of it comes from a concretionary zone at the base of a fine-grained, friable, greenish, micaceous, Pegu sandstone. He remarks that the water from springs or wells at this horizon is invariably salt while that from higher horizons is usually sweet. He remarks, in passing, that the local inhabitants regard the presence of a species of Euphorbia, *Streblus asper,* locally known as *okhnebin,* as indicative of the presence of good water. His observations in the area confirm this belief. In one case, Mr. Bradshaw noticed two wells on either bank of a small stream whose sandy bed was coated with efflorescent "*sapaya*" or soap-sand. The water in one of the wells was very salt while that in the other, which had been dug beside an *okhnebin* tree, was sweet. If this well site had been proposed in the ordinary way it would have been condemned without hesitation.

Yamethin District.

Waterless tracts occur in the three townships of Yamethin, Pyawbwe and Yanaung.

In the Yamethin township the tracts have been defined as Yamethin North, Yamethin West and Tatkon. The first has an area of about 25 square miles and contains sixteen villages with a total population of over 1,200 households. They possess tanks and shallow-wells but these dry up during the hot season, which usually lasts from April to June. The most southerly point of the tract is within one mile of Yamethin town, on Sheet No. 249 of the one-inch-to-one-mile survey, the geology of which was studied by Mr. B. B. Gupta in field season 1924-25.

All the affected villages lie on the alluvium of this sheet or the one immediately adjoining it on the south. This alluvium closely resembles the local varieties of the Irrawadian and it is difficult to distinguish between them. Characteristic of the Irrawadian are great thicknesses of loose sandstones, sand-rock and gravel, with very minor developments of sandy shales. The assemblage is not adapted for the storage of underground water in this region and, when it underlies the alluvium proper, is very liable to drain the latter of its water.

An experimental boring, in search of water, carried to a depth of 52 feet at Kadaing village, some years ago, was a complete failure;

passing through the shallow surface deposits it entered the underlying Tertiary rocks. It is impossible to compute the thickness of the alluvium in this dry tract without trial borings and so to give a conclusive opinion on its water-bearings potentialities.

It appears that there are wells close to some of the villages which do not dry up even in the hottest weather. Dr. Coggin Brown recommends that these should be tabulated and surveyed, in order that the portion of the zone in which perennial shallow supplies are available may be determined. Once demarcated, a shallow trial boring could be made and its behaviour under pumping investigated. It is already known, as a result of Mr. Gupta's work, that the present surface wells situated about Longitude 96° 10′ and between the villages of Hlwe-u and Kadaung, yield more water than those in the rest of the area around Yamethin. The former place is very close to the waterless tract of Yamethin North, though not actually within it. In the same manner a careful study of the prevailing conditions in the tract might lead to very useful conclusions.

The Yamethin West tract occupies an area of approximately 13 square miles, with its centre 8 miles west of Yamethin (Sheet No. 249). It is hilly and rises to a height of 1,014 feet in its south-western corner. The existing sources of supply are the Indawgyi and Shwe Chaungs, but if rainfall is deficient, water remains in these for short periods only and villagers have to make "sand wells" in the beds of the streams for periods which may extend up to six months. There are nine villages concerned, with a total of over 950 households between them. Indawgale and Kanma are situated on the Irrawadian rocks and the prospects of tube-well supplies near them are exceedingly poor. The remainder lie towards the head of a small alluvial basin almost surrounded by Irrawadian rocks. The alluvial deposits are probably thin, particularly to the south, about Thitse and Letpandaw. Shallow-wells have better chances of getting water further north, around Pauktaw, Zedaw and Kalamyaw.

The small Tatkon area (No. 3) about three square miles in extent is centred around Tatkon Railway Station at a height of 480 feet; it contains three villages with a total of 318 households. Tatkon itself is on alluvium but the Irrawadian rocks crop out within less than a mile, both to the west and north-west. The possibilities of good tube-well supplies here are very remote.

There are six waterless tracts in the Pyawbwe township, adjacent to one another and occupying an area of approximately 70 square miles on Sheet No. 248 of the one-inch survey. The geological survey of this sheet has not been completed.

The Paungdaw tract contains one village with 70 households. It lies at an elevation of over 1,000 feet on the edge of the Shan Hills. Although the area has not been geologically surveyed, the underlying rock is probably gneiss and tube wells are out of the question.

The geological conditions of the second tract– Yebyu, with two villages are quite unknown, but bordering the Yamethin plain as it does and lying at elevations of from 700 to 900 feet, this tract is probably not much better off than the first.

The third tract (Mogaungtaung) lies to the south of the Paungdaw tract. Its lower points are about 900 feet above sea level and its highest is at 3,461 feet. Nothing is known of its geology and its four villages, with a combined population of 110 households, are not shown on the one-inch map.

The Twinywa tract (No. 4) adjoins the Paungdaw tract on the north-west, and contains three villages with 103 households. The alluvial deposits are probably thin and the prospects of successful tube-wells are not good.

The Kontha tract (No. 5) lies to the south of the Twinywa area, and contains three villages with 170 households. The geological conditions are similar and the prospects of good underground water supplies are very remote.

Adjoining the Kontha tract on the west, but lying on the opposite side of the Samon, is the Sugyigon tract (No. 6) containing the single village after which it is named, with 117 households. Fruitless attempts have been made to obtain water here by digging wells up to 75 cubits deep, and the place, like those of the other tracts enumerated, depends on a tank which dries up in March, when the shortage has to be met from more favoured but distant localities. Shallow-wells might be tried in the direction of Yagyi, but the outlook is unpromising.

The Yanaung township contains one waterless area with six contiguous village tracts, lying in its south-western corner (Sheet No. 202). The chief source of supply is the Thitson Chaung but it fails in droughty years. The surface tanks dessicate about March and the people then resort to "sand wells" in the stream beds.

Fourteen villages, containing a total of 1,027 households, are involved. The area is occupied by Pegu rocks which were geologically surveyed by Mr. B. B. Gupta, in season 1923-24. From his descriptions of the rocks themselves and of the existing surface wells, it is concluded that if suitable sites for tube-wells could be found by more detailed examination of this area, the probability that the water, even if obtained in sufficient quantities, might be saline and unpotable, is enough to make the experiment hardly worth attempting.

Burhanpur Water Supply; Central Provinces.

The present water-supply of Burhanpur, derived in part from wells, in part from ancient aqueducts leading from the Utaoli river, and in part from a pumping station on the Tapti river, is becoming increasingly inadequate for a growing city. Mr. Crookshank was therefore asked to investigate the possibility of increasing the supply sufficiently to cover present and future requirements by the construction of a reservoir on the Utaoli river. The site which had been suggested is one about ½ mile below the village of Thatar. Here the river follows a narrow valley between two cliffs; that on the south bank is formed of basalt, while that on the north is made up of sandy clay with boulders of the trap. The boulder-containing sandy clay has been proved by borings to have a depth of about 60 feet. The excavation of the sandy clay in order to reach a solid foundation for the dam would be an expensive proposition and probably out of all proportion to the numbers likely to be benefited thereby. The scheme would necessitate an excavation 60 feet deep by 400 yards long in stiff sandy clay with numerous boulders, the construction of a dam 500 yards long by 90 feet high, together with a pipeline some 8 miles long. Mr. Crookshank points out that a site half-a-mile further upstream and immediately opposite the village of Thatar would involve much less expense, but would give a smaller storage.

Pachmarhi, Central Provinces.

Mr. Crookshank, in considering the water-supply of Pachmarhi, has advised that, after certain tests to ascertain the rate of percolation have been made, one of the existing wells should be deepened as a further experiment. He is at the same time favourably impressed with the alternative of tapping some of the streams and pumping the supply up to the town. At Zillahgad, west of the rifle range, water flows from a number of deep joint-planes and unites to form a clear

stream. A pumping station at this point, capable of raising the water about 200 feet, would go far to meet present requirements. Again, there is a small perennial stream north of the cemetery flowing through a narrow cut. By blocking the cut to a depth of 30 feet or so, a small deep tank would be formed, from which consumers could be supplied after pumping the water to a height of about 150 feet. This scheme, Mr. Crookshank thinks, would be cheaper than that suggested at Zillahgad, and would derive the additional advantage of the proximity of the Medical Officer's bungalow.

A dam on the Bainganga Nala, above the Golf Course is also worthy of serious consideration, since it would, in Mr. Crookshank's opinion, easily supply all present or future needs. The leakage from the existing dam near Pachmarhi is negligible and, as geological conditions at the site of the proposed dam are the same as those at the old dam, no serious leakage need be anticipated. Allowing for loss due to seepage and evaporation, Mr. Crookshank calculated that a reservoir having retaining walls of approximately 15, 20 or 25 feet would have a capacity of 2,000,000, 6,700,000, or 15,000,000 cubic feet respectively. Any of these would provide an adequate supply of drinking water, and either of the two larger ones would yield a surplus for irrigation purposes. With a run-off of 24 inches a year the catchment area is calculated to yield many times the above quantities of water.

Tube-well, Chideru, Mianwali, Punjab.

Mr. E. R. Gee was asked for advice regarding the water-supply of the village of Chideru (32° 32′ 30″ : 75° 46′ 30″) situated at the foot of the Salt Range about 14 miles east of Mianwali. The present water-supply is obtained from a spring within the Chideru Hills of the Range at some considerable distance from the village. To meet the demands of the village, it is proposed to sink a tube-well in the hope of obtaining sweet water for drinking purposes.

From an examination of the geological map and memoir by Mr. A. B. Wynne, *Mem. Geol. Surv. Ind.* Vol. XIV, 1878., it appears that to the south-east of Chideru for a distance of 1½ to 2 miles, the red salt marl crops out along the foot of the Salt Range, being followed upwards in normal succession by: purple sandstones; boulder beds of crystalline boulders in a clayey matrix; the Speckled Sandstone series—red, purple and variegated sandstones with lavender clays; the Carboniferous Limestone series, consisting mainly of

massive grey and white limestones; Triassic limestone and shale series.

A fault appears to repeat these strata higher up the slopes, the salt marl, etc., recurring in the upper courses of the stream which enters the plains just south of Chideru, and drains this area. The plains at the immediate foot of the Range in this locality are covered with a mass of boulder débris derived from the rocks of the vicinity.

Just east of the village the salt marl and purple sandstone beds die out, so that to the north-east for a distance of 3 miles to the gorge of the Bazar river the Carboniferous rocks crop out, together with a few inliers of the Speckled Sandstone (Upper Red Sandstone). Further north the Bazar river drains an area within which the salt marl again crops out. It is to be expected, therefore, that the drainage from the hills south-east and east of Chideru will be definitely saline, and any wells sunk in the alluvium at the foot of these hills would yield a supply unfit for human consumption. For the same reasons the water of the Bazar river, 3 miles N. of Chideru, and of the vicinity would be saline or brackish. Between Chideru village and the Bazar river, however, the drainage from the Carboniferous limestone which covers almost the whole of the area, should enter the boulder alluvium of the plains in an uncontaminated condition. As a result of percolation from the saline drainage to the north and south-east brackish water would doubtless extend outside the limits of these two drainage systems. It appears quite possible to Mr. Gee, however, that such percolation may not affect the whole of this intervening area, so that the prospects of obtaining sweet water to the north-west of Chideru, well away from the two areas of saline drainage above mentioned, are to say the least, hopeful. On these assumptions Mr. Gee suggests a site for the boring near the foothills, ½ to 1 mile north-west of the village.

With regard to the general water-supply of the Salt Range, villages on the southern slopes and at the foot usually obtain their drinking water either—

(i) From springs at the base of the Nummulitic limestone in the eastern part of the Range and at the base of the Carboniferous limestone of the middle and western parts of the Range.

(ii) From the streams above the outcrops of the salt marl,

(iii) From the rain-water which is collected in large artificial 'tanks.'

On account of the numerous outcrops of the salt marl at the foot of the Range, the boulder and clayey alluvium in the vicinity of the Range, yields in many places a brackish supply. The question of water-supply within these regions does not appear to have been commented on in any detail in the past, but will be borne in mind during the present re-survey of the Salt Range. The results of the Chideru boring will be very useful as a guide to similar operations in other parts of the Salt Range.

Water Supply, Dehra Dun Railway Station, United Provinces.

At the request of the Chief Engineer to the East Indian Railway, Dr. M. S. Krishnan was deputed, towards the end of September, to investigate the possibility of additional sources of water-supply for Dehra Dun Railway Station.

According to the Assistant Engineer to the East Indian Railway, the station at Dehra Dun, which is an important terminus, requires about 4,500-5,000 gallons of water an hour to meet all its needs. The present supply amounts only to about 1,800 gallons an hour and is derived from a spring on the eastern flank of the southern end of the Kalanga hill near Raipur (30° 18′; 78° 6′). As far as can be seen, the water issues at the junction of quartzites (above) and slaty rocks (below), but the whole is much covered by soil and débris fallen from above. The quartzite is a compact, white, massive variety in the fractures and joints of which the water seems to be stored. The water is soft and of sufficiently good quality to be used without treatment in locomotive boilers.

The water at the spring issues forth at three points close together, and flows over some 50 feet of soil before it reaches a tank whose dimensions are 4 feet by 4 feet by 4 feet. From this tank, two pipes, each three inches in diameter, conduct the water to the station. Low masonry walls have been constructed by the Railway authorities above and along the two sides of the spring area, so as to prevent the slipping of soil from above. At the time of Dr. Krishnan's visit, it was estimated that only half the amount of water from the spring went through the pipe. It had been proposed to instal a larger tank and pipe from which it was expected to secure a supply of about 2,500 gallons an hour.

The rainfall records of Dehra Dun show an average annual fall of 83·41 inches of which about 73 inches fall between June and September; the months of March, April and May are the driest.

Dr. Krishnan visited the wells in existence in and around Dehra Dun in order to determine the sub-surface water-level. This is on an average about 90 to 120 feet below the surface in Dehra Dun itself but deeper wells are known. Along the Saharanpur road to the south of the Bindal river, the water-level rises to very near the surface—between 12 and 20 feet—as seen in the wells at Niranjanpur (30° 18′; 78° 0′ 40″) and Majra (30° 17′ 30″; 78° 0′ 20″).

Dr. Krishnan suggests two ways in which an increased water supply can be obtained:—

(1) By improving the tapping arrangements at the spring so as to utilize all its water.

(2) By constructing wells at suitable sites.

The improvements suggested at the spring are:—

(*a*) The construction of a masonry floor or pavement to cover the area between the points of issue of the spring and the storage tank. As the outlets of the springs are in a circular arc, the pavement should be given a Y-shape with a depression running along the middle, the total area of pavement being about 2,000-2,200 square feet. This would greatly reduce waste by percolation into the soil.

(*b*) The storage tank should be of larger dimensions than the present one, and sufficient to store all the water from the spring.

(*c*) The present pipe feeding the station should be replaced by one of a larger diameter.

Dr. Krishnan considers that the above improvements would result in a supply of nearly 4,000 gallons an hour.

An additional supply will, however, be needed in the dry season and at times of heavy demand. For this purpose, the construction of a well is recommended. As there seemed to be no advantages in selecting a site north of the latitude of the station, the following two alternative sites, one near the station and the other just over a mile to the south, were considered suitable.

The first site was located in a small area about 200 yards east and south-east of the station, where water may be expected at a

depth of from 100 to 120 feet. As the Railway possesses a small area just east of and behind the quarters of the Railway staff, a well was suggested here. For a steady supply, it should reach a depth of, say, 150 feet from which it would have to be pumped up.

The second site recommended lies in a triangular area enclosed between Niranjanpur village on one side, and the Saharanpur road and the Bindal river on the other two sides. The sinking of a well to a depth of about 50 feet in this site is expected to yield an abundant and steady supply. While, therefore, the expenditure on the construction of a well here would be much less than in the first site, a pipe-line of about one-and-a-quarter miles would have to be constructed, and the water pumped up to the station in this through a difference in level of just over 100 feet.

Jhansi Water Supply, United Provinces.

The geological aspect of a scheme for the supply of drinking water to the Civil and Military station and to the Railway workshops and station premises of Jhansi. by the construction of a dam on the Ghurari Nadi, about 1 mile north of Babina Railway Station, was entrusted to Dr. Heron. Babina is 15 miles by rail south of Jhansi Junction. The dam consisting of earth, with a puddled clay core 3 or 4 feet in thickness, will be a little under a mile in length and about 70 feet high at its highest point above the present stream-bed, and will impound a sheet of water over 2 miles in maximum length and breadth, lying within the Orchha State.

The storage area is a wide and shallow valley, bottomed with alluvial deposits overlying "Bundelkhand gneiss." The Ghurari Nadi meanders through this, and the proposed dam will cross it close to the northern end. This stream is usually dry during the dry season.

A line of bore-holes, 25 in number, and spaced about 250 feet apart on the average, except near the stream where they are much closer, had been put down by a 2-inch Calyx hand-drill along the line of the proposed dam, and showed that the alluvium passed through consists of coarse angular sand with a varying admixture of yellow clay, these being the result of the disintegration *in situ* of the underlying "Bundelkhand gneiss" which is here an ordinary granite. The boring specimens are probably more sandy than the beds passed through, since a considerable proportion of the fine clay must have been lost in the boring, but even allowing for this, most of the

alluvium must be very incoherent and porous, and the clay core of the dam will have to be founded in bed-rock.

On the surface are patches of red and yellow clay and so-called "cotton-soil" up to 6 feet in thickness; the last is not the true black cotton-soil of the Deccan, but a dark grey clay coloured by vegetable carbonaceous matter and differs little from the red and yellow clays, all being light and loamy.

According to the boring records, only two holes, Nos. 12 and 13, went down to "hard rock," 10 others ended in "boulders"; a series of 7, situated to the south of the stream, are still in alluvium at depths of about 50 feet, and bed-rock is at an unknown distance below this.

The particular signification of the term "boulders," used in the boring records, as distinguished from "hard rock," was not apparent to Dr. Heron from the bore specimens, as in both cases they were cores of fairly sound granite, and the term "*moorum*," usually applied in the Deccan and Bombay to decomposed trap, is not understood in this case. The granite which crops out in the neighbourhood does not tend to form boulders on weathering, but smooth, bare surfaces, with only a thin weathered crust.

The Bundelkhand gneiss is locally a medium-grained and even-grained granite, tough, usually sound, and quite devoid of foliation. In colour it is mottled pinkish-red and dark green from the felspar and chloritised ferro-magnesian constituent respectively; quartz is inconspicuous in hand specimens. No pegmatite nor aplite veins were seen, and neither basic nor acid patches were observed, the only deviations from uniformity being broad and indefinite bands of coarser material with vaguely porphyritic felspars, and similar bands of very fine-grained felspathic microgranite. The latter is more resistant to weathering than the average granite, and gives rise to low whale-backed ridges running in a general N.E. S.W. direction, with the same trend as the bands of coarse-grained material and the great reefs of quartz which are such a conspicuous feature of Bundelkhand scenery.

The low rise against which the southern end of the proposed dam will abut, contains some of the coarser variation, while the more prominent hill at the north end is composed of the fine-grained rock. So far as can be judged from the borings, the bed of the site consists of the predominating medium-grained type.

The two vertical joint-systems of the granite run approximately in the above-mentioned N.E.-S.W. direction and at right angles to it, and, with the horizontal jointing, divide the rock into roughly cubical blocks of the order of a foot to a yard in side.

With regard to leakage, the granite would make a fairly sound foundation, and if, for the founding of the clay core, a trench several feet deep be cut in the bed rock to get clear of rotten rock and open fissures, and any cracks are grouted with cement, little loss need be anticipated. In any case, there is no better alternative available from a geological point of view, for nothing but Bundelkhand gneiss of the same character is found for many miles around Jhansi. It is perhaps hardly necessary to emphasize the fact that the alluvium is highly porous and that the clay core of the dam must everywhere be set into the trench in sound rock, and rammed well down into it.

The large amount of clay requisite for the core is a difficulty. The soil of Bundelkhand, from the nature of the underlying granite, is eminently light and sandy and probably no adequate deposits of true clay will be found within an economic distance. There are, however, on the site itself, patches of loamy clay already referred to, which Dr. Heron thinks, might possibly be suitable, and are at any rate worth a trial in bulk, to test their behaviour on puddling and on drying, under conditions similar to those to which the clay core will be subjected; these patches are the "cotton soil" in which bores Nos. 10, 11 and 12 started, and the "yellow clay" of bores Nos. 16, 17, and 18. The "red clay" of bores Nos. 14 and 15 appeared to be rather too sandy, but might also be tried. These deposits are shown in the boring records as being up to 6 feet in thickness; trial pits should be put down to that depth, or until sand is encountered, to ascertain the vertical and horizontal extent of these layers, and the plasticity and shrinkage of the material from these pits should be tested under as near as possible actual conditions.

GEOLOGICAL SURVEYS.

Bihar and Orissa.

During the field season 1927-28, the Bihar and Orissa party consisted of Dr. L. L. Fermor (in charge until the return from leave of Mr. Jones), Dr. Dunn and Dr. M. S. Krishnan. Mr. Jones after his return from leave inspected the prospecting work being carried out by the Tata

Iron and Steel Company, at their iron mines at Noamundi in the Singhbhum district. The borings to prove this area are being continued, but owing to the faulting and the hardness of the rocks, the work is necessarily slow. Mr. Jones also carried out a series of sieve tests on the powdery hæmatite which occurs in most of the iron ore areas. Samples from Noamundi, Gua, Buda and Pansira show the extremely fine nature of this material; more than 40 per cent. of it will pass through a 100-mesh sieve.

Gangpur State: Bihar and Orissa.

For some years past, systematic geological survey operations have been conducted in two somewhat widely separated tracts of Archæan rocks, namely the Nagpur-Chhindwara tract of the Central Provinces and Singhbhum and northern Orissa in Bihar and Orissa. In both these tracts certain areas have been surveyed in considerable detail but, owing to the fact that the general grade of metamorphism in the Central Provinces is higher than in Singhbhum, the schistose strata of these two tracts have not yet been correlated. A rough survey, made by Dr. E. Spencer of Messrs. Bird & Company for economic purposes, indicated that the tract in which limestone is being worked by several different operators in north-east Gangpur is probably an anticlinorium. In the centre of this anticlinorium certain unimportant deposits of manganese-ore were known to occur, whilst further to the south-west on the same line of strike is the important manganese mine at Gariajhor, also in Gangpur State. The Gariajhor manganese occurrence was determined many years ago to belong to the gondite series of the Central Provinces by Dr. Fermor to whom, in view of Dr. Spencer's work, it appeared that Gariajhor and these minor manganese-ore deposits might supply the key to the linking up of the Central Provinces with Singhbhum, the survey of which had already been carried by Mr. Jones's party up to the edge of the Gangpur anticlinorium. In addition, the discovery by Dr. Spencer of albite crystals in the limestones of the Raipur tract and by Dr. Fermor of evidence in specimens supplied by Dr. Spencer of two periods of folding in certain biotite-garnet-schists collected in the centre of the supposed anticlinorium, indicated that the survey of this tract would prove not only important stratigraphically but interesting petrographically. This task was allotted to Dr. M. S. Krishnan, and during the field-season of 1927-28, he surveyed some 720 square miles of country, of which a small portion lay in that part of Singhbhum adjoining the north-east

corner of Gangpur State and the remainder in Gangpur State including the southern edge of the Ranchi district. The south-eastern margin of this tract joins the ground already mapped near Manharpur and Jeraikela Stations.

The result of this new work is to confirm Dr. Spencer's suggestion and to reveal the detailed stratigraphy of an anticlinorium stretching from the Singhbhum boundary in sheet No. 73-F/S.W. to the western edge of 73-B/S.E. It was not possible in one season to carry this mapping as far as Gariajhor to the west, but this Dr. Krishnan hopes to accomplish in the present field-season. The work done shows, however, that the manganese occurrences in the centre of the anticlinorium are mineralogically similar to the gonditic occurrences in the Central Provinces. These gonditic occurrences occur in ground where there is much alluvium and soil at the surface, so that their precise relationship to the other rocks is not determinable; but from their general position there seems no reason to dissociate them from the schistose rocks in the interior of the anticlinorium with which they are associated, so that if the result of the present season's field work is to show that the manganese-rocks of Gariajhor are similarly placed, then the problem of correlation of the Sausar series of the Central Provinces —to which the gonditic rocks belong—with the Iron-ore series of Singhbhum, will be greatly facilitated. The succession found by Dr. Krishnan in Gangpur is as follows:—

1. Alluvium.
2. Pegmatite and granite-gneiss.
3. Epidiorite.
4. Sericite and mica-schists.
5. Schistose conglomerate.
6. Mica schists.
7. Calcitic crystalline limestone.
8. Dolomite.
9. Mica schists.
10. Gondite.

Divisions 4 to 9 appear to form one continuous series of rocks of which division 4, seen in the neighbourhood of Manharpur, appears to be definitely identifiable with the slaty shales of the Iron-ore series of Singhbhum, with a slightly higher grade of metamorphism. It is not yet known whether all the strata below division 4 are to

be correlated with already known divisions of the Iron-ore series, or whether they include portions of a lower downward succession. The horizon, 10, of gondite belongs presumably to the same succession, but as this is a matter of great importance, it is being treated for the moment as a point not yet settled. Of these 6 horizons—4 to 9—limestones and dolomites crop out along both margins of the anticlinorium, and the schistose conglomerate only along the southern margin. It was thought possible at first that this conglomerate might mark an unconformity; it seems more likely now, however, that this rock does not indicate a structural break, but rather a period of very coarse sedimentation, as may be inferred from the gradual though rapid transition to fine-grained schists on either side. The rocks of this tract, according to Dr. Krishnan, show progressively advancing metamorphism when followed in a north-westerly direction. Thus in the neighbourhood of Manharpur, the argillaceous rocks are sericite-schists, similar to the slaty shales of the Iron-ore series of south Singhbhum and Keonjhar, but showing a slightly higher grade of metamorphism. The northern and north-western parts of the area mapped show muscovite and biotite schists with well-developed garnet, staurolite and tourmaline, the garnet giving rise to knotted schists. The epidiorites occur along both edges of the anticlinorium, apparently overlying the limestones and dolomites. It seems difficult to treat them as an integral portion of the stratified succession, as they appear to show intrusive relationship towards the schists; they are, however, themselves schistose and must have been intruded into the stratified succession prior to the latest period of folding and to the intrusion of the pegmatite and granite gneiss, which, at one place, cuts the epidiorites. Amongst the schists are carbonaceous rocks—both schists and quartzites. The carbonaceous quartzites are usually fine-grained and have an outward resemblance to the banded hæmatite-quartzites of south Singhbhum and Keonjhar, showing the fineness of banding, crumpling, folding and faulting on a minute scale characteristic of the hæmatite-quartzites.

Bombay.

The examination of the Kanara and Belgaum districts of Bombay was continued by Rao Bahadur Vinayak Rao with the assistance of Sub-Assistant A. K. Dey. A brief summary of their work will be found under "Manganese" (pp. 58-59).

During the field season 1927-28 the Burma Party consisted of Dr. J. Coggin Brown (in charge), Messrs. E. J. Bradshaw, C. T. Barber, P. Leicester, V. P. Sondhi, B. B. Gupta and Dr. H. L. Chhibber.

Burma Party.

Before being deputed to the Rangoon Water Supply Survey Party Mr. P. Leicester mapped geologically Sheets 95 I/4 and E/11 and parts of Sheets 95 E/15 and E/16 in the Ye-Lamaing Township of the Amherst district. He observes that this area, which is bordered on the west by the Bay of Bengal, by Siam on the east and Tavoy on the south, is continuous geologically with the Tavoy district and has geological features strongly resembling those described by Dr. J. Coggin Brown and Dr. A. M. Heron in their memoir on that region.[1]

Amherst District.

The Mergui series, an assemblage of highly folded and indurated sedimentaries, is extensively intruded by bosses of granite some of which are of considerable size. In the southern portion of the area the hills stretch from the frontier on the east to the sea on the west, but in Sheet 95 E/16 the coastal plain, so conspicuous a feature of the country to the north, develops and broadens northwards to be broken only by the discontinuous coastal granite ridges. It is here that the laterite, which covers such large areas farther north, first appears bordering the hills and covering most of the low ground except the alluvial areas.

The predominating rock of the Mergui series is a hard blue slate roughly cleaved and often quartzitic; associated with it are quartzites which are in places somewhat argillaceous. Typical argillite was not met but a shaly variety was found in one locality.

Mr. Leicester observed two outcrops of sandstone conglomerate, with well rounded pebbles, at the junction of the Ananbon Chaung with the Ye Chaung (Long. 98° 6′ 18″; Lat. 15° 6′ 8″) and on the left bank of the Ye Chaung, ¼ mile downstream from the junction.

The strike of the sedimentaries varies from N. 10° W. to N.40° W., the most general direction being N. 20° W., with a steep variable and often vertical dip. The banding and veining of the coastal granite is found to be parallel to the general strike of the sedimentaries.

In the neighbourhood of the granite contact, the rocks of the Mergui series are metamorphosed into micaceous quartzites, quartz-

[1] *Mem. Geol. Surv. Ind.*, Vol. XLIV, Pt. 2.

schists, gneissic and felspathic quartzites and schists and paragneiss. From the presence of quartz and felspar in many of the metamorphosed sediments it would appear that the granite masses have contributed a considerable amount of silica to the argillaceous rocks where these come in contact with them.

The typical granites of the area are pale, medium-grained biotite-granite and hornblende-biotite-granite, usually with sphene as an accessory mineral.

Within the area examined the occurrences of granite are :—

(1) Coastal range.
(2) Central boss connected with the coastal granite in the south.
(3) Northern termination of the frontier boss in the south of Sheet No. 95 I/4.
(4) Small inlier at the junction of the Ye and Yinye Chaungs, Sheet 95 I/4.

The best outcrops of granite are to be seen along the sea-coast and on the islands which lie just off it. Attention is drawn to the extensive development of micro-dioritic rocks and melanocratic micro-granites which occur in intimate association with the hornblende-biotite granites. The granites do not contain tourmaline but are remarkable for their abundant accessory sphene and epidote. Primary calcite is common as an accessory mineral in the dioritic rocks.

The micro-diorites and micro-granites are compact, dark green rocks of very fine texture. The micro-granites contain quartz, orthoclase and subordinate oligoclase; hornblende and biotite are present in equal or even greater proportions than the quartz and felspar, and sphene is usually present as an accessory mineral.

The micro-diorites commonly contain oligoclase and andesine in excess of orthoclase and microcline, abundant hornblende and biotite and occasionally traces of quartz. Sphene, epidote and calcite are often present as accessory minerals.

The dark rocks occur as lenticular masses and wisp-like patches in the granite and as veins cutting through it, but in places the granite is seen in the form of veins cutting the basic rocks. Both the granite and the dark rock are penetrated by small quartz veins and again by veins of aplitic biotite-granite.

In Mr. Leicester's opinion the dark fine-grained rocks are melanocratic differentiation products of the granite magma, and their arrangement as lenticles and veins running parallel to the direction of the strike of the sedimentaries, points to the granite having been disturbed before its consolidation by the movements which folded the Mergui series.

On the south of Bath Bun Island, opposite the mouth of the Ye River, a pale granodiorite overlying a typical diorite was observed.

A large sill of lamprophyre was seen on the northern side of Kawkari Taung (Long. 97° 48′ 38″; Lat. 15° 20′ 53″).

Lower Chindwin and Shwebo Districts.

Mr. V. P. Sondhi resumed the survey of the Lower Chindwin and the Shwebo districts in Upper Burma and mapped parts of Sheets 84 J/14, 84 N/4 and 84 N/3, and the whole of Sheets 84 N/7 and 84 N/2, where he recognised the following series:—

Alluvium.
Irrawadian series.
Pegu series.
Pondaung series.
Olivine basalts and tuff deposits.

A flat tract of alluvium stretches over a large area west of the river Chindwin, covering practically the whole of Sheet 84 N/4, the central portion of 84 N/3 and the southern portion of 84 N/2. The gradient rises gradually to the east in Sheets N/4 and N/3 and to the north in Sheet N/2, till it passes to the broad, low hill range, composed of rocks of Upper Tertiary age, running in a N.N.W.-S.S.E. direction, and forming the watershed between the river Chindwin and the Mu river drainage systems.

The Irrawadian series is widespread in this area and is represented mostly by incoherent sand containing variable proportions of clay. In Sheet 84 N/4 a small section is seen in the stream at Nyaungbinthe (Lat. 22° 8′; Long. 95° 15′) in contact with the bedded shales of the Pegu series, probably with a faulted junction, as is suggested by the steep westerly inclination of the latter. East of Yeganzu (Lat. 22° 11′; Long. 95° 15′) the series is exposed as bright sand of the usual type, with grit, quartz pebbles and pieces of fossil wood.

In Sheet No. 84 N/3-7 the rocks forming the above-mentioned hill range are divisible into the Irrawadian and the Pegu series,

on lithological grounds. The former surrounds the Pegus on all sides except the southern and consists of sandy clay for the most part. Near Thapan (Lat. 22° 22′; Long. 95° 12′) it is reddish brown in colour and contains plenty of silicified wood and calcareous concretions, but the lithology changes to fine-grained sand-rock with occasional intercalations of ferruginous grit, in the neighbourhood of Myothitchaung (Lat. 22° 25′; Long. 95° 14′). The characteristic features of the series in Sheet 84 N/7 are the rarity of fossil wood, the abundance of small calcareous concretions and the frequent occurrence of pale tenaceous clay containing calcareous nodules sometimes with a core of perfect crystals of calcite of an intense white colour.

The country in Sheet No. 84 N/2 possesses typical Irrawadian scenery and is occupied by a flat stretch of sand from end to end. At Yedwet (Lat. 22° 11′; Long. 95° 15′) it encloses a mass of pure tenaceous clay which is used by the villagers for pottery manufacture. About two miles east of Yedwet, salt water oozes out of the sand-rock over a large area and forms a stream flowing west. Such a phenomenon is rare in the porous Irrawadian sands, but the spring here seems to owe its origin to the existence of the impervious mass of clay which appears to have checked the underground flow of the water; it is charged with salts of sodium, calcium, potassium, etc., mostly carbonates. The lithology of the series in other parts covered by this sheet is very monotonous.

The topography of Sheet 84 J/14 is somewhat diversified by the presence of Plateau Gravel rich in ferruginous concretions and fossil wood which tend to stand out as mounds and hillocks as the accompanying sand is washed away.

West of the Chindwin the Irrawadian lies directly over the Pondaungs, in the south-west corner of the sheet. East of the Pondaung inlier it occurs in the form of a series of low hills, often concealed from view by debris from he Pondaung hill. It shows steep inclinations near its junction with the Pondaungs, due to the post-Irrawadian disturbance which seems to have resulted in a fault along the entire length of the inlier. The basal Irrawadian exposed here is very fine-grained sand-rock of a pale brown colour.

The Pegu inlier forming the core of the hill ange in Sheet 84 N/3-7 is easily recognisable from the surrounding Irrawadian sand-rock by the deeper water lithology and the stratified nature

of its component rocks. The latter consist of calcareous sandstone, shales and bedded clays, but the junction between the two series is rarely well defined.

A change in the rocks indicating deeper water deposits is very noticeable from north to south. Near Thapan at the northern end of the inlier, the deposits are of a decidedly shallow-water facies, consisting mostly of soft sandstone and thin beds of sandy shale, with large pieces of fossil wood, but three miles south, in the neighbourhood of Mondu (Lat. 22° 19′; Long. 95° 14′) fine-grained calcareous sandstone and greenish shales are seen with an appreciable decrease in the fossil wood contents. Further south near Palangyin (Lat. 22° 7′; Long. 95° 15′ 30″) bedded shales become the predominant rock.

Though the lithology of the southern portion of the inlier is that of a deep-water deposit, there is evidence of periodical undulations of the floor on which deposition took place. In the Mondu Chaung ripple-marked sandstone is seen interbedded with the regularly calcareous sandstone, and in the Palangyin Chaung a conglomerate of a light green colour, consisting of peculiarly shaped elongated shaly pebbles in a shaly matrix, is found.

The general structure of the inlier resembles that of an asymmetric anticline with its apex very near the village of Gwebinde (Lat. 22° 17′; Long. 95° 15′ 30″). A strike fault runs through the apex along the line joining the two basalt hills shown as points "882" and "800" on the map. Normally the dips are to the N. E. and S. E., but near the main fault they change rapidly, and west of it the beds dip steeply to the W. and S.W., sometimes approaching the vertical. The fault is known to continue a long distance to the south in similar rocks and there is evidence of its continuity to the north for a few miles beyond the Pegu inlier.

In view of the faulted nature of the anticline and the manifestation of igneous activity near its apex, the structure in this area cannot be regarded as suitable for the accumulation of oil.

In the south-west corner of sheet 84 J/14 an inlier of the Pondaung beds is exposed, standing in conspicuous contrast to the surrounding yellowish Irrawadian sand-rock in respect of its colour, lithology and physiography. The component rocks are of a deep dirty green colour, consisting of hard sandstone, conglomerate, shale and clay. The eastern boundary, faulted throughout its

length, presents a steep escarpment to the plain stretching in that direction.

For the greater part the rocks consist of conglomerate possessing practically the same characteristics at different horizons. The pebbles, ranging in size from a walnut to boulders one foot across, are of igneous and metamorphic parentage and are perfectly rounded and waterworn. Large pieces of fossil wood are quite common in the conglomerate and coarse sandstone; the shales, on the other hand, contain carbonised impressions of leaves and twigs.

The structure of the inlier is that of an asymmetric anticline, with a long, gently-inclined, western limb and a sharp eastern face. The Irrawadian series lies over the Pondaungs with identical dips on all sides, the Tabyin Clays and the Pegu series, which should have been between the two to complete the normal sequence of the Upper Tertiary beds, being absent in this area. The absence of these two groups may be explained in either of two ways. The Pondaung rocks may have become a land surface before the deposition of the Tabyins and the Pegus, and remained as an island while the latter two were forming, so that the Irrawadian series, which is a land deposit, covered them directly: or, the area may have become a land surface after the deposition of the Pegu series and remained so for a long period during which the Pegus and the Tabyin Clays were denuded away, before the Irrawadian silts were deposited. In the latter case a considerable interval or unconformity has to be imagined between the Pegus and the Irrawadian; this is contrary to the evidence obtained from the examination of these series in other regions. In the first case we have to suppose the Pondaungs in this area to have remained under the influence of weathering agents for the whole of the time which intervened between their deposition and the present day; this explanation seems more feasible in the absence of any conclusive evidence.

The widespread igneous activity that commenced while the Irrawadian beds were being deposited and continued periodically to sub-Recent times, is represented in the area by a number of small basalt and basaltic tuff occurrences. The different periods of activity were apparently subject to similar environments, as is suggested by the similarity of their mode of occurrence and their composition, a noteworthy characteristic of them all being that

the lava in no case seems to have been hot enough to affect the country rocks thermally to any appreciable extent.

About three miles north of Alon, in Sheet 84 N/4, is a low hill of olivine basalt, presenting a somewhat precipitous face to the west, and merging gradually into the general level of the country to the east. The grey lava is very vesicular and partially jointed, and is extensively quarried for road metal.

Other volcanic occurrences of the area are situated along the main fault line of the Pegu inlier, at various points, in the form of basalt plugs, explosion craters, and basaltic tuffs. In Sheet 84 N/7 a conical hill of basalt, marked "822" on the map, cuts through the rocks of Upper Tertiary age at Kyaunggon (Lat. 22° 17′; Long. 95 15′). The basalt is heavy and compact and slightly amygdaloidal.

About eight miles north of this hill, near Inde (Lat. 22° 23′; Long. 95° 12′), a remarkable manifestation of igneous activity occurs in the form of a denuded remnant of an explosion crater, similar to those reported last year. The ejectamenta consist of basalt blocks, tuffs and lapilli, the successive layers of coarse and fine material pointing to the intermittent nature of the explosions.

About seven miles north of the Inde crater a hump-shaped hill marked "875" and "897" on the map, cuts through the Irrawadian sand and forms a prominent landmark over the surrounding country. The hill has a steep face to the south and slopes gently to the north, towards which the basalt dips. The striking characteristic of this occurrence is the prevalence of a highly vesicular and pumiceous olivine basalt which weathers very easily.

Between the Inde crater and Okpo Taung a number of small tuff exposures were seen, interbedded with the Irrawadian series. Prominent among them are two tuff beds, dipping S.W. at high angles, exposed south of the 26th mile on the old road between Budalin and Ye-U.

Lower Chindwin District.

Mr. B. B. Gupta resumed his survey work in the Lower Chindwin district and completed Sheets 84 J/11 and J/12. He also mapped Sheet 84 J/10, with the exception of a small area in the north-west.

In Sheet 84 J/10 a new series of rocks is exposed besides the typical formations, Irrawadian, Pegu, Yaw and Pondaung. This has been called the Natma series from the village of that

name. It extends from Mahu in the north to Saingde in the south and lies between the Shwethamintaung on the west and the foot of the Mahudaung range in the east. It is composed essentially of soft clayey sands interbedded with white and greyish white sandstone and attains a thickness of nearly 1,300 feet. It is conformable both to the Irrawadian above and the Pegus below.

The Natma series as a whole is very soft and weathers away easily. A large amount of the deposit, especially near the base, has been denuded and washed away. The more clayey beds throughout the series are coloured or stained a red of various shades. Where they are much weathered, which is usually the case with the beds near the base, they are exposed as red earth with no visible stratification. Argillaceous sandstones appear in mottled red and grey shades and sometimes in mottled buff and grey tints. White sandstones are exposed a little above the base of the series, but they generally wear a greyish look owing to the presence of extraneous impurities. Towards the top of the series, current-bedded sandstones, often interbedded with clayey rocks and of no great thickness, occur.

Chelonian remains and bones of larger animals were seen in the Natma series in some of the *chaungs*, but none of them was found *in situ*, and none has been identified even generically. Some of them are regarded unquestionably as the remains of mammals by Mr. Gupta.

Blocks crowded with small gastropods, tentatively referred to the Viviparidæ, were also seen in the beds of most of the rivers that cut through this series. Silicified wood in large quantities was met with in the lower beds of the series.

Various views have been held regarding the age of these beds. Dr. Stamp mapped them as Pondaungs, perhaps confusing them with the chocolate marls of the older ormation.[1] In a more recent paper, written jointly by Messrs. Pinfold, Day, Stamp and Chhibber, they have been referred to the Pegus[2].

Considering their lithological similarity and geological position, Mr. Gupta is inclined to correlate the Natma beds with the 'Red Bed' of the Yenangyaung area, in spite of the fact that the former are conformable both to the Pegu and to the Irrawadian. Un-

[1] *Trans. Min. Geol. Inst. Ind.*, Vol. XVII, Pt. 3, pp. 161-180.
[2] *Trans. Min. Geol. Inst. Ind.;* Vol. XXI, Pt. 3, pp. 151-152.

fortunately, the fossil evidence has not yet proved helpful in determining the exact age of the Natma series.

Fossils are very rare in the area described. In the Irrawadian, a single vertebrate referred to *Stegodon* sp. was found in one locality only, about three miles N. of Yagyi. It was not *in situ*, but had been transported from a neighbouring place. In the Pegus two fossiliferous clay beds were discovered in Sheet 84 J/10, the first in the Lawin Chaung and the other in the Hatti Chaung. In both localities *Batissa crawfurdi* Noetl. was noticed, as well as a ribbed variety of a lamellibranch belonging to the Unionids; this ribbed shell is, however, very rare in the second locality. The Pondaung Sandstones, which yielded a rich crop of vertebrate fossils in the Myaing area of Pakokku, are almost barren in the north; a fragment of a jaw bone of *Metamynodon* sp. was, however, obtained from them on the Chinbyit-Aingma cart track, about four miles and 1½ furlongs west of Chinbyit. Fossil wood was noticed in the Pondaungs, the Pegus and the Irrawadian. In several places in Sheet 84 J/10, partially carbonized wood was found both in the Irrawadian and in the Pegu. Fossil wood occurs plentifully in the beds of the Natma series, a little above the base.

On the western part of sheet 84 J/12, which was mapped by the late Captain Walker, a synclinal fold was seen. The axis of what appears to be the same fold was noticed north of latitude 22° 25′ on the western margin of sheet 84 J/11. A large strike fault, running almost N.-S., separates the Pondaungs from the Irrawadian in all the three sheets. Near the fault zone the rocks—Irrawadian as well as Pondaung—are disturbed. The latter have developed an apparently asymmetrical anticlinal fold, with the longer arm to the west, in which the dip averages about 30°, while on the shorter it is very variable, sometimes approaching vertical. Sharp local flexures are also visible in the eastern limb in some sections.

Three inliers of Pondaungs occur in the Irrawadian in Sheet No. 84 J/10, the beds of both the formations dipping to the west. There is a total absence of the Yaws, the Pegus and the beds of the Natma series from these inliers and the Irrawadian beds seem to overlap the Pondaungs. In the easternmost of these inliers no dip is seen in the rocks of the Irrawadian formation and it is consequently difficult to be sure if an overlap has taken place.

The same is the case with the Medin inlier, which was examined last season and which was considered to be a case of unconformity. From the examination of other inliers in the area, Mr. Gupta is now inclined to hold that in all these cases the Irrawadian beds overlap the Pondaungs. In the Myaing area, where the same overlap is observable, the inlier is bounded by a fault on one side. In the present area no convincing evidence of a fault has been noticed in any of the sections where the inliers are exposed.

Myitkyina District.

In the course of his work in the Jade Mines region, Dr. H. L. Chhibber mapped parts of Sheets 92 C/2, C/3, C/6 and C/7 in the Kamaing subdivision of the Myitkyina district. He has divided the strata met with into the following series and rock types:—

Alluvium.
Volcanic rocks.
Uru Boulder Conglomerate.
Grano-diorite.
Crystalline complex.
Tertiaries.
Peridotites and serpentines.
Limestone.

Small outcrops of limestone are common in the area. The colour of the rock varies from cream to black, but various shades of grey and blue are also present. In places the rock approaches marble, in others it is brecciated. About one furlong south-west of the confluence of the Hwehka and Nammon Chaungs, the limestone near the contact of the peridotites and serpentines has been metasomatically replaced by silica. Macroscopically it appears to be a black chert but under the microscope it is seen to consist of an extremely fine mosaic of silica. Perfect rhombohedral crystals of dolomite are developed in the rocks, undoubtedly as a result of the contact effect of the serpentine intrusion. Thin sections revealed the presence of *Fusulina elongata*, *Fenestella*, *Textularia*, and various forms of *Globigerinidæ*. The presence of these fossils tends to prove that the limestone is of Permo-Carboniferous age.

A big mass of peridotite, which in places has partially or wholly altered to serpentine, extends for about two miles north of Tawmaw (Lat. 25° 41′ 13″; Long. 96° 15′ 28″) to the latitude of Haungpa (Lat. 25° 30′ 48″; Long. 96° 6′ 15″). Bleeck depicted it as two

separate outcrops but it is really one continuous mass as seen in the Uru Chaung below Mamon (Lat. 25° 35′ 10″; Long. 96° 15′ 57″). There is another outcrop of the same rock, exposed south and east of Hwehka, which must be continuous underground with the main mass, but crystalline schists intervene for a little over one-and-a-half miles west of Kadonyat (Lat. 25° 3′ 20″; Long. 96° 15′ 46″).

A thick mantle of red soil covers the rocks, the ferruginous contents of which have been concentrated in places to form iron ores. A number of types have been described, the most important being altered dunite, mica-hornblende-peridotite, diallage-peridotite, diallage-perknite (pyroxenite) and amphibolite. Although the types are partially serpentinised in places a number of varieties of true serpentine also occur in the area. The most prevalent one is a massive dark green mineral, but antigorite possessing a thin lamellar structure is by no means uncommon; the thin foliated variety, "marmolite", with a pale green colour, also occurs. Occasionally seams of finely fibrous chrysotile, with a pale green colour and silky lustre, are found as fine lenticles and thin seams in the ordinary massive variety. It is remarkable that these rocks, especially towards the south, have been highly brecciated.

The Tertiary rocks are developed on the east of the area and on the road to the Jadeite mines; a good section exists on the mule track between Namting (Lat. 25° 38′ 45″; Long. 96° 27′ 29″) and Lonkin (Lat. 25° 39′; Long. 96° 22′), a distance of about 8 miles. Their thickness must be considerable since in places the strata are almost vertical. They consist of sandstones, shales and conglomerates. The sandstones are of various colours and shades, coarse to medium in texture and sometimes pebbly. They contain many minerals but quartz and felspar (both orthoclase and plagioclase) are predominant. Grains of epidote, glauconite, chlorite and serpentine are quite common; while muscovite, biotite, hæmatite, chromite and calcite also occur in some sections. Small grains of graphite and graphite-schist are also present showing that the graphite-schists are older than the Tertiaries. In some sections grains of jadeite were observed proving that the intrusion of the jadeite dyke must have occurred prior to the deposition of these rocks. All particles lie in a siliceous matrix. Some of the sandstones are calcareous but the majority of the specimens are of an argillaceous character.

The shales are generally of a greyish colour and a thin section shews dark brown carbonaceous matter with a considerable amount of calcite interspersed through it. Some quartz and a little mica are also present. A number of small microscopic forms belonging to the family *Globigerinidæ* are also to be observed. These fossil forms were only observed in the shales from Hwehka (Lat. 25° 29′ 3″; Long. 96° 16′ 43″), which tends to prove that a small inlet of the deep sea existed in its neighbourhood. This must have undergone very rapid oscillations as is shown by the inter-bedding of conglomerate boulders containing jadeite. Many boulders of jadeite-bearing conglomerate were collected from the neighbourhood of Hwehka and other places; they contain various types of serpentine including antigorite, peridotite, amphibolite, hornblende-graphite-mica and quartz-schist, etc., proving that these rocks were in position when the Tertiary rocks were being deposited. Bands of finely jointed, black, carbonaceous limestone also occur interbedded with these rocks.

The occurrence of coal and lignite in these rocks has been referred to elsewhere. Small trunks of dicotyledonous fossil wood were seen about a mile west of Namting (Lat. 25° 38′ 45″; Long. 96° 17′ 29″). Impressions of plant leaves are not infrequently observed; they have been referred to *Tetranthera hwekonsis* in Dr. Bleeck's paper.[1]

The crystalline schists form a crystalline complex which encircles the peridotites and serpentines; they are said to be products of the differentiation of the same magma. They are all ortho-schists and comprise a number of basic igneous rocks, ranging from diorites and gabbros to pyroxenites and perknites, merging into one another. The prevailing and most striking type is epidiorite, especially where it contains white circular phenocrysts of saussurite; originally this rock must have been a gabbro. The next most marked type is a greyish black graphite schist which sometimes contains pseudomorphs of limonite, most probably after garnet. Other types which are quite common in the area include glaucophone-, hornblende-, chlorite-, kyanite- and quartz- schists. Specimens of an interesting rock were obtained from about half-a-mile north-east of point "1,361" on the map (92 C/6). It consists of green hornblende (smaragdite) with some clear olivine,

[1] Bleeck, A. W. G.: "Jadeite in the Kachin Hills, Upper Burma." *Rec. Geol. Surv. Ind.*, Vol. XXXVI, (1908), p. 257.

diopside, a little augite and titanite. The rock is the hornblendite of Dana or hornblende-perknite of other authors. A similar rock has been described as an ejected block from the Twindaung crater in the Lower Chindwin region.[1]

The age of the schist cannot be ascertained with certainty since the igneous activity extended over a long period. This activity first manifested itself during the early Tertiary period and ceased towards late Tertiary times. Boulders of some of these schists are found in the Tertiary conglomerates, and representatives of almost all of them are included in the Uru Boulder Conglomerate to which a Pleistocene to sub-Recent age has been assigned. At Kadonyat (Lat. 25° 3′ 20″; Long. 96° 15′ 46″) interesting evidence is forthcoming. A tongue of these schists protrudes into the Tertiary strata which thin out towards the east, while the jadeite-bearing conglomerate is overlain by glaucophane-chlorite and talcose schists.

Three outcrops of grano-diorite have been mapped. The biggest has an extension of 3½ miles in a N.-S. direction, as seen on the Saingmaw-Hwehka road; it is intrusive into serpentine in the north and into the Tertiaries in the south. Another occurs west of Mawkalon village (Lat. 23° 29′ 55″; Long. 96° 18′) and ends a little north of the deserted village of Namlan (92 C/7). Very probably it is continuous with the grano-diorite observed a little south of Sie-taung village. This is also intrusive into the serpentine which near the junction has been rendered schistose, with the development of epidote, but it touches the Tertiaries also in the Hwehka Chaung about ¾ mile south-east of Mawkalon; the latter have been baked and hardened while the black shales near the contact are almost vertical. The third outcrop lies in the Mikilin Chaung, with boulders of breccia of the same rock lying on the surface of grano-diorite. Macroscopically the rock is medium grey in colour and is sometimes porphyritic with a coarse texture; it is really a grano-diorite but all varieties from true granite to quartz diorite are present.

Quartz porphyry occurs as small injections in the grano-diorite, etc., as, for example, on the Saingmaw-Hwehka road, about a mile E.N.E. of "1,879" (92 C/6). The phenocrysts are

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[1] "Late Tertiary Igneous Rock of the Lower Chindwin Region," *Trans. Min. Geol. Inst.*, Vol. XXI, 1927, p. 216.

quartz and felspar with irregular patches of amphibole and chlorite, but the main interest lies in the groundmass which is composed of fully or partially developed spherulites with an extremely fine mosaic of quartz and felspar. Another small intrusion of similar porphyry occurs in the Saingmaw Chaung about one-and-a-quarter miles south-east of Saingmaw (Lat. 25° 35′ 0″; Long. 96° 17′ 30″). A soda porphyry is intrusive into the Tertiaries in the Kadonyat Chaung, about half-a-mile W.S.W. of Hwehka. Specimens of a syenite porphyry, intrusive into the serpentines, were obtained near the deserted village of Sabyi (Lat. 25° 37′ 30″; Long. 96° 16′ 15″). Quartz veins were also observed in a few places. These rocks being intrusive into the Tertiary appear to be either of very late Tertiary or of post-Tertiary age. There seems little doubt that there is a genetic relationship between the grano-diorite, quartz porphyry, quartz veins, rhyolite and rhyolite breccia of this region. All these are of the same (post-Tertiary age) and undoubtedly represent the intrusive dyke and extrusive phases of the same igneous activity.

The Uru Boulder Conglomerate has so far been taken to be alluvium of Recent age and Dr. Bleeck mapped it as such. It consists of water-worn boulders of all sizes ranging from a few inches to several feet in diameter, embedded in red earth but occasionally in sand-rock. Its thickness must be considerable – about 1,000 feet in places; cliffs over 300 feet high, composed solely of this conglomerate, are fairly common. As it is the latest formation, except the modern alluvium of the region, it includes boulders of almost every older rock; these consist of altered peridotites, and all varieties of serpentine (massive, antigorite, chrysolite, marmolite, etc.), rhyolite, siliceous breccia and quartz (colourless, pink, and smoky). Boulders of crystalline schists are very common—mica-schist, quartz-schist, glaucophane-schist, anthophyllite schist. Boulders of grano-diorite, diorite and epidiorite also occur. Small boulders of chromite, hæmatite and limonite are occasionally observed. Jadeite too is found in the form of boulders. Sometimes beds or lenticles of sand-rock occur intercalated in conglomerate.

The following section is generally observed in the Boulder Conglomerate workings for jadeite :—

1. Alluvium of variable thickness.
2. A layer of pebbles and gravels (*kadi kyaw*).

3. Boulder conglomerate (*kyauk kyaw*).
4. Sand rock with boulders (*thai kyaw.*)
5. Bed-rock (*phali.*)

It appears that the area has been affected by earth movements subsequent to the Pleistocene period, since in places low dips—seldom exceeding 10°—are seen. The age of this formation is most probably Pleistocene to Sub-Recent.

Both acidic and basic volcanic rocks exist in the area. Boulders of rhyolite and rhyolitic breccia are quite common and rest on the peridotites and serpentine, crystalline schists, the Boulder Conglomerate, etc. At the following localities these boulders were seen in quantity:

1. On the Lonkin-Tawmaw road, near mile "36" (map 92 C/6) and at irregular intervals up to the 37th mile.
2. In the neighbourhood of Lamong village (Lat. 25° 37′ 36″; Long. 96° 15′ 17″).
3. On the Lamong-Ningma Hka path, about ⅓ mile west of point "2,070" (map, 92 C/6), and continuing for a distance of a little less than half-a-mile.
4. A little less than half-a-mile south-west of Hkakam Bum, point "2,020" (map, 92 C/6).
5. About half-a-furlong west of the deserted village of Manna (Lat. 25° 36′ 43″; Long. 96° 16′ 15″). This outcrop demonstrates the post-Pleistocene or Sub-Recent age of these eruptions, because the boulders here rest on the Uru Boulder Conglomerate of Pleistocene age.
6. A few boulders were observed about a mile west of Nammaw village (Lat. 25° 38′ 20″; Long. 96° 15′) near point "2,346" (map, 92 C/2).
7. Near Hwehka (Lat. 25° 29′ 3″; Long. 96° 16′ 43″), the boulders occur in the Hwehka Chaung, in the small streams near Kadonyat and also south of the latter place.

Besides the boulders of rhyolitic breccia large boulders of serpentine breccia were also observed in a number of places as, for example, near Lamong village. But they are more common around Hwehka, as in the Hwehka, Mikilin, Mogyaung and Sapya Chaungs. Another important outcrop of the same formation exists

about a mile south of Hwehka. It is noteworthy that in the Mikilin Chaung boulders of grano-diorite breccia were seen resting on the small outcrop of grano-diorite exposed in the stream.

The boulders sometimes measure over several feet in diameter. Fragments of serpentine and crystalline schists embedded in a siliceous matrix constitute the bulk of the clastic fragments. The rocks have undergone considerable silicification subsequently. Boulders of pale yellow, or hæmatitic jasper also occur. An interesting specimen of porphyritic rhyolite was picked up from the Manaung Chaung, about one mile E. N. E. of Hpakan (Lat. 25° 36′ 38″; Long. 96° 18′ 40″). The phenocrysts of quartz, orthoclase, albite and biotite occur in a groundmass which shows fluxion structure sweeping around the phenocrysts; the presence of albite in the phenocrysts places the rock in the Toscanite family of Washington.

Specimens of basic volcanic rocks were collected between Namting and Lonkin (Lat. 25° 39′ : Long. 96° 22′).

In the small stream west of the 26th mile (map, 92 C/6) on the Kamaing-Tawmaw mule track a number of partially worn, dark, fine-grained, basaltic boulders occur. A small block of basalt was also picked up N.N.W. of the 27th mile of the same road. This rock is similar to, if not identical with that which Dr. Bleeck designated as picrite porphyry. It resembles the picrite-basalts described by Holmes[1] from Mozambique except that the colour of the augite in the present case is green. A boulder of hornblende-andesite resting on Tertiary rocks was collected about ½ mile east of the 27th mile on the Kamaing-Tawmaw road. It bears a perfect resemblance to the hornblende-andesite of Tounggala, described from the Mount Popa area[2], and also to some of those from the Lower Chindwin region.[3] All these rocks lie on the same volcanic line.

Mr. P. Leicester, in the course of his work in connection with the Rangoon Water Supply Survey, mapped geologically portions of Sheets 94 C/3, 94 C/7 and 94 C/8 in the Pegu district.

Pegu District.

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[1] Holmes, A., "The Tertiary Volcanic Rocks of the District of Mozambique" *Q. J. G. S.*, Vol. LXXII, 1916, p. 244.

[2] *Trans. Min. Geol. Inst.*, Vol. XXI, p. 276.

[3] *Op. cit. sup.*

The rocks occurring within the area in order of their respective ages are:—

(3) Alluvium clay and river silt.

(2) Irrawaddy Series (?)—current-bedded sands, sand-rock, soft sandstones shales and clays (Pliocene).

(1) Pegu Series—sandstones and shales (Oligo-miocene).

The Pegu series is represented within the area examined by unfossiliferous, yellow, buff and brown friable sandstones (often micaceous) and shales, with occasional bands of hard grey calcareous sandstone. These rocks form the main portion of the range to the west of longitude 96° 10′ and are well exposed along the banks of the streams which flow eastward from the hills to join the Ngamoyeik Chaung. With the general strike varying from N.-by-W. to S.-by-E. in the southern part of the area, to N.-by-E. to S.-by-W. farther north, they dip steeply to the east beneath the Irrawadian series.

The last geological survey of the Pegu district was conducted between the years 1861 and 1873 by W. Theobald whose Memoir "On the Geology of the Pegu"[1] was published in 1873. The geology is rendered on a rough ¼-inch-to-the-mile topographical map, presumably the best obtainable at that date.

Theobald mapped the hills west of Wagyaung as belonging to the Pegu series and his description of the lithology agrees with that of the rocks to be seen in the neighbourhood of Wagyaung.[1] (Sheet No. 94 C/3).

The rocks occurring east of Wagyaung, stretching eastwards between the broad range of the Yoma on the north and the alluvium of the plains in the south, were classed by Theobald as Lower Delta Alluvium.[2] He divided the Delta Alluvium into two portions:—

(*a*) An upper division, the Older Alluvial Clay, a remarkably homogeneous clay forming the fertile coastal plains which are everywhere cultivated for rice, and

(*b*) A lower division, consisting of sands and gravels.

In the neighbourhood of Prome, Theobald distinguished some beds which he termed the Fossil Wood Group[3] and which are

[1] *Loc. cit.*, p. 80.
[2] *Loc. cit.*, p. 52.
[3] *Loc. cit.*, p. 59.

traceable into Upper Burma, but he later agreed to change the name to Irrawaddy Sandstone.[1] This name was subsequently transformed into Irrawadian series by Sir Edwin Pascoe.[2] As a result of his observations in the neighbourhood of Rangoon, Mr. Clegg was inclined to believe that the Lower Older Alluvium of Theobald is the southern representative of the Fossil Wood Group or Irrawadian series, its surface here being considerably lateritised, and Mr. Leicester is entirely in accord with this view.

In Sheet No. 94 C/3, the boundary between the Pegus and the overlying Irrawaddy series is not at all well defined and the uppermost beds of the Pegu series pass gradually and apparently more or less conformably into the Irrawadian series.

From the western boundary line, which runs approximately north and south at a distance about two miles west of Wagyaung village (Long. 96° 10′ 55″; Lat. 17° 22′ 48″) the Irrawadian beds stretch eastward and southward to the plains where they disappear beneath the delta alluvium. The lower beds are exposed in the banks of the Ngamoyeik and Wagyaung Chaungs to the west and again on the banks of the Mahuya Chaung a little to the east. They comprise shales and soft, shaly, micaceous sandstones with bands of hard clay and beds of sand.

Above these beds, which strongly resemble the Pegus, is a series of current-bedded sands, sand-rock with bands of clay and soft, bedded, micaceous mudstone. These mud or silt stones reveal distinct ripple-marks. In places, the sand-rock is prevalent and answers to the description of the sand-rock of Upper Burma, of which Sir Edwin Pascoe writes,[3] "the greater bulk of the Irrawadian series, however, consists of loose, friable, clean, light-yellow sandrock, highly current-bedded, frequently iron-stained, and often containing concretions of hard calcareous sandstone".

There is a particularly good exposure of this sand-rock on the left bank of the Ngamoyeik Chaung about ½ mile south of the village of Kyawzaw (Long. 96° 11′ 49″; Lat. 17° 20′ 52″). Here is a cliff, forty to fifty feet high, of pale yellow, friable sand-rock which can, in most places, be scraped from the cliff face with a stick or even by hand. Towards the base of this section distinct but irregular bedding is visible and bands of micaceous sandstone

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[1] *Rec., Geol. Surv. Ind.*, Vol. XXVIII, p. 151.
[2] *Mem, Geol. Surv. Ind.*, Vol. XL, p. 29.
[3] *Ibid.* p. 73.

occur. The sand-rock above contains clay nodules, some small and others reaching the size of a football. Remarkable wisps of clay are to be seen and in places thin broken bands of hardened clay resembling a sun-cracked layer of mud, resting on and covered by sands; the sequence suggests estuarine or lacustrine conditions during deposition. The upper part of the section is sandy but partly lateritised and consequently reddish brown in colour. The whole is traversed by faults which become somewhat obscured in the upper part of the soft sand-rock. From observations of exposures in the streams the structure of the area is found to be a series of small anticlinal and synclinal flexures with axes running approximately N. by W. to S. by E.

North of the Mweni (Long. 96° 11′ 5″: Lat. 17° 19′ 23″) the ground is much faulted and, as a consequence, the strike and dip are in places somewhat irregular. Just south of Pokta a curious, irregularly shaped outcrop of hard calcareous sandstone containing rounded clay or shale pebbles was found bordering a large fault. The faults here are all closed and usually filled with slickensided shaly material. Some of these faults can be traced for a considerable distance and it is interesting to see how they appear to have affected the course of the streams in their vicinity.

The only good surface exposure of the Irrawadian seen to the east was a section of sand and shaly clay, with a slight dip to the south-east, on the left bank of the Lagunbyin Chaung (Long. 96° 21′ 25″: Lat. 17° 18′ 30″).

On the ridges the rock is lateritised to as great a depth as 30 feet over considerable areas, though actual laterite is not found at this depth. The lateritisation becomes more pronounced as one proceeds south-eastwards where laterite clay is prevalent and where laterite is common. Trial pits and bores sunk on the ridges reveal below this laterite cap a series of sands, clays and sandy clays; these may well be the upper beds of the Irrawaddy series. In many of the pits there is no evidence of stratification and clays and sands occur as irregular lenticles but in one pit on the ridge to the south-west of Wagyaung, lying between the clays, were distinct bands of stratified clay. The rock in this pit shows a dip in agreement with the general structure as worked out from the exposures in the stream-beds.

Borings sunk through the alluvium met sands and clays beneath, resembling those obtained from the borings in the ridges. The

low level borings, carried out during the dry months, soon struck water showing that the rocks must be saturated all the year round. Some bores were sunk to a depth below mean sea level and in three instances sand was forced up the casing. From the borings it was quite impossible to trace any form of stratification of the sands and clays which appear to be lenticular. Mr. Leicester, however, considers it possible that these beds may originally have shown some rudimentary stratification which has been obliterated by the action of the underground water, for the current-bedded sands and laminated clay bands exposed at the surface are of an extremely soft nature, and any stratification which these may have possessed would be destroyed in a bore sunk below the ground water level. Moreover, in a boring south of Wagyaung, laminated sandy micaceous clay (shaly clay) was found interstratified with sand at a depth of 55 feet below the surface, whereas another boring, only 75 feet distant from the first, passed through blue clay and sandy clay and showed no trace of the shaly material. It appears possible that the Irrawaddy series here passes gradually into the lower beds of the Estuarine Alluvium without any visible break.

The alluvium is represented by homogeneous blue, green and brown clay with occasional sandy layers; it extends from the coast in the south, northwards up the valleys of the rivers and streams which descend from the north. For convenience the alluvium may be divided into two divisions, (*a*) the alluvial clay and (*b*) river silt.

Everywhere the alluvium is covered by rice fields. As is the case in the greater part of Burma, the villagers living by the upper waters of the streams have cultivated every patch of alluvium which is neither marshy nor yet so high as to be left dry when the silt-laden streams flood the fields during the monsoon. The delta alluvium of the plains is of great depth but as the foot-hills of the Yoma are approached the covering diminishes in thickness. Borings near Intagaw (Long. 96° 28′: Lat. 17° 10′) show no sharp dividing line between the alluvium and the rocks beneath.

More recent in age than the alluvial clay are the sand and silt found in the beds of the streams along their banks, and the fine silt deposited over the alluvial clay of their basins by the streams when in flood.

At Wagyaung, the Ngamoyeik Chaung and the lower waters of its tributaries flow through the valley about 25 feet below the level of the fields and between steep banks. It would seem that streams originally meandered over the valley continually changing their courses, but for some reason such as uplift, increased rainfall or catchment, they suddenly gained greater powers of erosion and deepened their winding channels. Mr. Leicester remarks that the argillaceous nature of the alluvial clay as compared with the arenaceous silt, and the sharp boundary between the two at the river banks, make the alternative possibility that the river built up the valley while in its present course, less probable.

The silt is pale yellow-brown and is composed principally of extremely fine quartz grains and mica, undoubtedly derived from the rocks of the Pegu and Irrawaddy series.

Over considerable distances may be traced one or two bands of compact and cleavable, though very soft and friable, silt about a foot in thickness. The bands are flexured displaying remarkably smooth and regular curves.

At some of the bends of the stream three distinct terraces may be traced generally about 2, 5 and 10 feet above the stream bed. Over most of their length the streams have cut down into the Irrawadian and Pegu rocks beneath, revealing excellent exposures, but half-a-mile north-west of Kyawzaw village (Long. 96° 11′ 22″ : Lat. 17° 21′ 31″) the Ngamoyeik Chaung flows on a bed of silt 30 feet thick. The cause of this variation is not traceable, but in view of the extensive faulting in the vicinity it is possible that the ground has been let down here by faults.

Rising a few feet above the alluvium of the valley of the Ngamoyeik Chaung are a few inliers of lateritised Irrawadian clays and sands. Some of these 'islands' however appear to be composed of alluvium, though, owing to partial lateritisation, distinction is difficult. This would mean that the streams when in flood have recently been denuding and carrying away material from the flood plain rather than depositing, and this is borne out by the number of trees and shrubs, perched on pedestals, about four or five feet above the level of the fields. The trees must have protected these pedestals from being worn away with the rest of the land surface.

In the region traversed, the surface of the Irrawaddy series has been lateritised over considerable areas and, while laterite

is common, the ridges are nearly everywhere capped by lateritic material which has not yet been converted into true laterite.

Material from test pits and borings shows every grade from fresh unaltered sands and clays to laterite rock; lithomargic and quartzose laterite are common.

The laterite clay is the most prevalent material capping the ridges. Over short distances a passage from sand through sandy lateritic clay to laterite clay may be seen and the change may be traceable in a single pit in many instances. In many pits rounded quartz pebbles are to be found scattered through the laterite clay in the same manner as they are seen in the unaltered sands.

Bearing in mind the process of formation of laterite it would appear from the above observations that at least some of the laterite cap has formed as a result of alteration of the sandy material. It is noticeable that, as a general rule, not without exceptions however, there is a capping of laterite clay on the crest and upper slopes of the ridges while in the lower points, cols and upper portions of the stream beds the material is sandy and often unaltered sand. This, according to Mr. Leicester, appears to be a question of drainage. It would seem that the laterite does not form easily in well drained ground and possibly, where sandy material has been left unaltered, springs have formed more easily and these low points have been eroded still further.

Sagaing and Shwebo Districts.

Mr. E. J. Bradshaw resumed the survey of the Sagaing and Shwebo districts, and completed the geological mapping of Sheet No. 84 N/16. The rocks exposed in the area have been placed in the following divisions:—

1. Recent . . .	Alluvium.
2. Pleistocene . . .	Plateau Gravel, Plateau Red Earth, Calcareous Grit.
3. Mio-Pliocene . .	Irrawadian series.
4. Oligo-Miocene . .	Pegu series.
5. Archæan . . .	Mogok series.

The Archæan is represented by members of the Mogok series; gneiss with bands of crystalline limestone, marble, and subsidiary schists. These rocks form a prominent ridge with a maximum height of 1,334 feet on the right bank of the Irrawaddy River along the eastern margin of the sheet surveyed. There is little to add to the description of the rock types given in the General Report

for 1927.[1] About two miles south of Tonbo the ridge bifurcates. The eastern limb is composed of massive white marble of the Mogok type, with subsidiary gneiss; the western is of gneiss with subsidiary bands of crystalline marble and schist which are usually to be found on its western flank. The valley between is filled with Upper Tertiary rocks which overlie the gneiss, the outcrops of the Archæans thinning rapidly northwards. At Kokko Chaung the eastern limb disappears. The western limb is much attenuated northwards with a decrease in the height of the ridge and towards the north of the sheet exposures are sporadic, the Archæans here being almost completely covered by Tertiary rocks. There are western outliers of gneiss at Talaingywa and north of Tamagan.

Mr. Bradshaw is of opinion that the rocks which form the low hills between Saye and Ondaw, along the southern margin of the sheet, are probably Upper Pegu in age. A similar age is attributed to the rocks which make up the hills at the south-western corner of the sheet and the greater part of the high ground which forms a low and discontinuous ridge running north and south from Ondaw in the south to Tachantha in the north. This high ground is some three miles wide at the south but decreases both in width and elevation northward.

In the Saye-Ondaw hills the predominant rock type is a false-bedded, coarse, loosely consolidated sandstone, fawn or greenish grey in colour. Lenses and thin, discontinuous shells of more coherent sandstone are common and there are frequent intercalations of fawn or greenish shales which are sometimes calcareous. A common rock is a thinly bedded grit with numerous rounded concretions or quartz pebbles. The beds of loose fawn sandstone may be up to 50 feet in thickness, the hard shells are seldom more than 2 feet thick and more often only 6 inches or so, while the shales vary in thickness from a few inches up to about 10 feet. A typical section in a cutting on the Public Works road immediately east of the village of Ondaw is as under:—

From above downwards:—

9. Calcareous grit and gravel.
8. Loose, coarse-grained, yellowish-fawn sandstone with thin bands and concretions of compact sandstone passing imperceptibly into

[1] *Rec., Geol. Surv. Ind.*, Vol. LXI, pp. 100-101.

7. A rapid alternation of loose or compact sandstone with thin beds of paper shales.
6. Loose, yellowish-fawn sandstone.
5.[1] Fault; sandy fault-rock, a mass of small calcareous concretions.
4. Yellowish-fawn sandstone with thin, sometimes discontinuous bands and lenticular concretions of compact sandstone. The loose sandstone shows strong current bedding and small slip-faults are common.
3. Loose, coarse, fawn sandstone.
2. Gritty sandstone with small rounded cavities marking shale concretions.
1.[2] Friable, gritty, micacous sandstone with thin beds of friable, fine-grained, flaky, greenish-fawn sandstone.

In the high ground at the south-western corner of the sheet the section is but slightly different. The upper beds are of loose fawn sandstone with intercalated shales. The lower beds of the loose sandstones and shales contain concretions, often of large size, of more compact sandstone whose shape resembles that of curling-stones. The presence of fossil wood at this horizon is not uncommon and emerging water is usually heavily charged with alkaline salts in solution which are subsequently precipitated to form "*sapaya*" or soap-sand. The beds below are of fawn sandstones and shales and friable fine-grained, greenish-fawn micaceous sandstone and shales followed by somewhat coarser fawn sandstone with thin, ferruginous sandstone.

Similar sections again occur in the high ground which runs from south to north from Ondaw to Tachantha. The rocks include reddish or very light coloured sandstones and shales with spring water containing "*sapaya*". These rocks often contain numerous, spherical sandy concretions which are usually roughly aligned parallel to the bedding planes. These concretions consists of a shell of sandstone cemented with calcareous salts and enclosing a core of friable sandstone. They break like onions into concentric shells. Their average diameter is about one foot and they have evidently been formed *in situ*.

The hills between Saye and Ondaw, along the southern margin of Sheet 84N/16, form an elongated dome with the major axis running

[1] The total thickness of 5-9 is about 60 or 70 feet and the dip is steep.
[2] The total thickness of 1-4 is about 1,200 feet and the average dip is low.

more or less W. N. W. to E. S. E. The southern flank does not appear on this sheet. The dips on the northern flank are gentle. On the western flank there is a narrow zone of gentle dips. The field evidence points to the existence of a broken and faulted fold. In general the dips are low and the crest of the anticline can usually be traced though false-bedding is common and the dips have a tendency to follow surface features such as *chaungs*. Small faults are very common and are too numerous to map on a scale of 1 inch to a mile. Frequently the prevalent dip is locally reversed in the immediate neighbourhood of these small faults or slips.

That portion of the group of hills which is shown at the south-western corner of the sheet is also part of a dome with the major axis running roughly N. W. and S. E.

The high ground between Ondaw and Tachantha is an anticlinal fold pitching northwards and forming subsidiary domes. The fold is asymmetric with gentle dips on the western flank. The crest runs close to the eastern boundary of the outcrop. The dips on the eastern flank are exceedingly steep, often vertical and sometimes overfolded. There is evidence of faulting and the fold is almost certainly broken near the crest.

There is evidence of more than one direction of stress for on the west of the western flank the prevailing dips are first to the west and then, west of the crest, swing southwards until the narrow zone of steep dips is reached. East of the eastern flank the ground is covered with Recent or Pleistocene deposits but at Ywathit (22° 9′ 20″ : 95° 50′ 30″) about 1¼ miles east of the crest there is an exposure of fine-grained, friable, greenish-fawn, micaceous sandstone dipping towards the east at 5°.

Apart from fossil wood and a doubtful fish's tooth there is no fossil evidence as to the age of these rocks. Mr. Bradshaw considers, on stratigraphical grounds, that they are probably Upper Pegu in age and has mapped them as such but thinks there is a possibility that the uppermost beds, a small percentage of the whole, may ultimately prove to be Irrawadian if and when more conclusive field evidence can be accumulated. Mr. Bradshaw has subsequently remarked a close lithological resemblance between these rocks and those of the Pyalo stage as exposed in the Singu Oilfield, but considers that too much weight should not be attached to a resemblance which may be fortuitous.

These structures, particularly those of the Saye-Ondaw hills and the hills at the south-western corner of the map, are all suitable for the accumulation of petroleum. No field evidence o its occurrence was noted and Mr. Bradshaw considers it unlikely that the zone is petroliferous, forming, as it does, part of that eastern belt of Pegu rocks which has proved barren whenever tested by the drill.

The Irrawadian series is represented by light coloured, loosely consolidated, coarse-grained sandstones with frequent intercalations of ferruginous grit and conglomerate, and basal beds. These rocks cap the ridge of Archæan rocks which attains its maximum development along the southern half of the eastern margin of the map; northwards the elevation of the ridge decreases. Southwards the Irrawadian beds are found only in the valley between the bifurcation of the Archæan ridge and on the eastern flank of the eastern limb. Very occasional remnants of the Irrawadian occur on the western flank of the western limb and are usually too small to map. As the elevation of the ridge decreases to the north the extent of the Irrawadian outcrop increases until almost the whole of the high ground is composed of these rocks. Apart from the small remnants on the western side of the ridge which have a westerly dip, the general dip is from 10° to 20° due east, and the structure is an asymmetric anticline with the western limb almost entirely removed by erosion.

As compared with the Pegu sandstones the Irrawadian strata are lighter in colour and coarser in texture. They are characterised by strong current-bedding which often obscures the dip and by the presence of abundant quartz pebbles, usually rounded but sometimes sub-angular. These pebbles occur both as stringers or free. The final characteristic is the presence of frequent intercalations of highly ferruginous grits and conglomerates.

The basal beds of the light coloured Irrawadian sandstone show considerable lateral variation in character. Near the base of the sandstone it is common to find spherical concretions of indurated sand or grit with small rounded boulders of quartz forming the core of the concretions. A general coarsening in the texture of the sandstone is noticeable and at its base it is often inclined to be conglomeratic. This sandstone series rests, apparently unconformably, on a curious clay-rock which averages about

100 feet in thickness. It is usually separated from the sandstone by a thin, calcareous parting and includes occasional rounded boulders, usually of quartz but sometimes of gneiss, or sandy lenticles. Below the clay-rock there are sometimes very coarse ferruginous conglomerates consisting of rounded pebbles or boulders of white or rusty quartz in a dark, ferruginous matrix with intercalcated shales usually reddish in colour and containing numerous small boulders of quartz and gneiss. The average thickness of the shale and conglomerate zone, as distinct from the overlying clay-rock is about 250 feet.

In one of the sections the clay-rock was seen to be dark chocolate in colour, greasy to the touch. Downwards the shale loses its greasy appearance and becomes a speckled, chocolate, gritty rock. In the main its junction with the Irrawadian is fairly regular but in places it juts up into the sandstone and there can be no doubt that the junction is unconformable. The general impression is of Irrawadian sandstone lying unconformably on an ancient alluvium. Mr. Bradshaw has mapped these basal beds separately and considers that at present their age must be regarded as doubtful. They do not resemble typical Pegus and may represent or be derived from, the weathered surface of the green schist seen interbedded with the gneiss on the western flank of the ridge.

Pleistocene deposits cover a considerable part of the sheet mapped by Mr. Bradshaw. Typical Plateau Gravel is found capping the Irrawadian sandstones on the right bank of the River Irrawaddy and consists of well-rolled boulders of quartz averaging the size of a cricket ball. The gravel is undoubtedly derived from the disintegration of the ferruginous conglomerates interbedded with the Irrawadian sandstones and does not occur elsewhere on the sheet.

Plateau Red Earth is also found capping the Irrawadian and, occasionally, in the high ground west of Yedwingaung. A considerable area north of Kadu Lake and west of Kyaungbyu Lake is covered by red sand and grit or reddish sandy soil probably derived from the weathering of the underlying fine-grained, micaceous Pegu sandstone. Frequently this reddish sandy soil is calcareous; sometimes it contains nodules of *kankar*.

Pleistocene deposits flank all the outcrops of the older rocks. West of the Archæan ridge they take the form of a comparatively

fine-grained quartz gravel, sometimes ferruginous and almost always calcareous. Close to the ridge the gravel is coarse in texture, contains numerous boulders of gneiss and quartz and finally merges imperceptibly into the debris on the western flank of the ridge. The rocks constituting the high ground between Ondaw and Tachantha are also capped or flanked by Pleistocene deposits, which are usually ferruginous sand, grit or gravel, very commonly calcareous. Fossil wood is occasionally found on the north of the eastern flank and is often abundant on the southern and western flanks.

Resident Geologist, Yenangyaung oilfield.

Mr. C. T. Barber continued to act as Resident Government Geologist, Yenangyaung until the 9th March 1928, when he was followed by Mr. E. J. Bradshaw. The Superintendent of the Burma Party and all Assistant Superintendents subordinate to him are *ex-officio* members of the Advisory Boards at Yenangyaung and Chauk constituted for the control of these oil-fields. Normally, however, the Resident Government Geologist at Yenangyaung is the only one able to attend the meetings of the Boards.

Mr. Bradshaw made inspections of the Padaukpin, Minbu, Palanyon, Yathaya, Lanywa, Yenangyat and Sabe oilfields; frequent visits were also paid to the Singu and Yenangyaung fields. In connection with the Yenangyaung field it is proposed to prepare maps showing the water sands encountered and isolations adopted in representative wells in each of the "Water Areas" into which the Reserves at Yenangyaung, are divided.

As a result of the general tightening of control over the outfields in Burma, investigations were made or are being made into the condition of all shut-down wells in the Padaukpin, Yenanma, Minbu, Palanyon, Yathaya, Ondwe, Kabat, Lanywa, Yenangyat, Sabe, Pakkoku and Indaw oilfields; the system of plugging adopted in all abandoned wells is also being examined.

Advice was given on the subject of increasing the vacuum at present applied to all wells in the Reserves at Yenangyaung. This important problem involves the mechanism of the movement of oil through sandy reservoirs, including the nature of the driving force and the viscosity, surface tension and temperature of the oil; the effect of dissolved gases on the mobility of oil; the importance of gas-oil ratios and gas conservation; the relative values of gas as a motive force and as fuel; the degree of exhaustion of

the oil-sands in the Reserves; the effect of the application of vacuum on interference between wells, on parafination and on sanding and other working difficulties; the cumulative effect of vacuum on the production of oil and gas since its application in 1923; and, finally, the question of the probable effect of vacuum-application on ultimate recovery.

A note is in course of compilation suggesting methods for the reduction of evaporation losses. The suggestions provide for the different collection and transport systems adopted by the several operating companies. At present evaporation is the cause of a considerable loss both to Government in revenue as well as to the Companies.

A note was compiled on the subject of interference between wells and the effect of well-spacing on gas-pressure and production, with special reference to the Reserves of the Yenangyaung Oil-field.

The system of water reports has been revised and steps taken to ensure their accuracy. It has been found that the well records submitted to Government are not always sufficiently complete. It is proposed to improve the present form of well-log and to introduce a system of summarised well-history. Fifteen hundred well-slips have been obtained and it is proposed to prepare modern graphic logs of all wells. Graphic logs will be of assistance in correlation and for rapid reference, but their preparation will be a work of some magnitude.

During the 16 years which have elapsed since a member of the Department was last posted to Yenangyaung, a great mass of data has accumulated. At present more or less incoherent and inaccessible, its conversion into intelligible and useful form will take time. A start has been made by plotting comparative production graphs analysing the total quarterly production from the Yenangyaung field for the past fourteen years into 16 different heads according to companies and areas. It is hoped similarly to analyse the Singu production while the production of the Burmah Oil Co., Ltd., from the Yenangyaung, Singu, Yenangyat and Minbu fields has already been plotted for the same period. If possible it is proposed to accompany each of these graphs with an explanatory note describing the cause of each rise or fall in production. Such graphs, with their explanatory notes will form a convenient basis for compiling an account of the recent history of

the fields. Graphs are also being plotted to show the recent decline in value and amount of the production from hand-dug wells in the Reserves at Yenangyaung.

The Central Provinces Party.

During the field-season, 1927-28, the Central Provinces Party comprised Dr. L. L. Fermor (in charge), Mr. H. Crookshank, Dr. S. K. Chatterjee, and Sub-Assistant D. S. Bhattacharji. Dr. Fermor remained for a large part of the period at headquarters, and his proposal to pay visits of inspection to Dr. Chatterjee and Mr. Bhattacharji was frustrated by the illness of the former and the fracture of an arm by Mr. Bhattacharji who slipped on a rock in the jungle.

Chhindwara and Narsinghpur districts.

Mr. Crookshank continued his mapping in the northern Satpura tract and completed during the season the survey of Sheet 55 J/14 and of the southern portions of Sheets 55 J/13 and 55 N/1, the survey of these two latter sheets being carried up to the edge of the Narbada alluvium. The area surveyed this season lay partly in the Chhindwara but mainly in the Narsinghpur districts. Mr. Crookshank has now completed the survey of a considerable tract of the Satpuras and has written a connected and useful report on the geology thereof. The following is the list of the formations mapped :—

Recent	Soil cap, and alluvium.
Deccan Trap series . . .	Flows, inter-Trappeans, dykes, and sills.
Gondwana	Upper and Lower.
Archæan	The Sausar series and granitic gneiss.

Attention has been drawn in previous years to the remarkable intrusive masses and sills in the Deccan Trap occurring in the Gondwanas of northern Chhindwara and southern Narsinghpur. Petrographically the rock making up the larger intrusive masses is a coarsely crystalline one resembling a gabbro in hand specimens, but more properly described as a dolerite on account of the presence of interstitial glass. This rock is similar to that constituting the great Deccan Trap sill of Korea State.[1] In the Korea sill Dr. Fermor detected evidence of sinking of the olivine crystals, a phenomenon which he subsequently confirmed in his study of the basaltic lava flows of Bhusawal.[2] Mr. Crookshank accordingly collected in the field

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 156, (1914).
[2] *Rec. Geol. Surv. Ind.*, LVIII, pp. 119-197, (1925).

specimens from various levels in the sills of northern Chhindwara in order to ascertain if the same phenomenon there prevailed. The principal constituents of these intrusive dolerites are labradorite, augite, iron-ore and glass with, as minor constituents which are not always present, olivine, biotite, quartz and apatite. There is also much secondary amorphous material, referred by Mr. Crookshank to chlorophæite. The order of crystallisation is olivine, felspar, augite, iron-ore, and apatite. Detailed observations showed that in most cases olivine is absent near the upper portions of the sills and present in the middle portions, thence onwards becoming increasingly abundant towards the base. Out of 7 sills investigated, 5 showed marked sinking of olivine, one gave an inconclusive result; in the 7th not only was there no sinking, but olivine was abundant in the upper portion of this sill, a relatively thin one.

Concurrently with the increase in the amount of olivine as one passes downwards in a sill, the specific gravity is found to increase. As an example, one may mention the sill one mile west of Salalkhera (22° 41′ : 78° 46′) in the Narsinghpur district from which Mr. Crookshank collected a series of specimens representing a total thickness of 265 feet. A specimen taken 20 feet below the top showed no olivine and a specific gravity of 2·95, whilst in the specimens near the base of the sill olivines were very abundant and the specific gravity was 3·03. In another example the specific gravity showed an increase from 3·024 near the top to 3·045 near the base. Unusual minerals for the Deccan Trap detected by Mr. Crookshank were quartz and biotite. Quartz was seen in several thin sections from the upper parts of sills. As the quartz commonly contains minute hairs of apatite, the quartz was deduced to be primary in origin. In one thin slice Mr. Crookshank detected what he considers to be biotite partially altered to chlorophæite. Other observers have occasionally detected traces of biotite in the Indian basalts, but the mode of occurrence has been such as to make it difficult to confirm the observation. Mr. Crookshank suggests the possibility that biotite was once common, but has been destroyed in the final stages of consolidation at the time when palagonitisation caused the conversion of much of the olivine and original glass to chlorophæite.

Various abnormal types of dolerite were noted. One of these from Bamni (22° 32′ 30″ : 78° 42′ 30″) in the Chhindwara district is slightly more acid than usual and shows under the microscope biotite, some quartz and much perthite. Whether the more acid character is due

to the incorporation in the basaltic magma of material from the overlying sandstone, or whether the rock represents an extreme case of differentiation of the sill, of which it forms the upper portion, has not yet been determined. A special search was made for evidence of contact alteration of sandstones and clays by the intrusive dolerites. An exceptional case of fusion of impure sandstone was detected as well as evidence of marginal silicification and discoloration. Mr. Crookshank made some laboratory tests on clay taken from contacts with the intrusives, and determined that they begin to fuse at about 1,000° C., from which it is deduced that the temperature of the intrusive magma must have been less than this figure. Another interesting phenomenon is the occurrence of "sandstone dykes" in the dolerites. These occur near the Gondwana-dolerite junction and may be as large as 100 yards long and only a couple of yards wide. It is suggested that minor apophyses from the doleritic intrusion have cut off elongated slices of the sandstone and that owing to the flow of the magma, these may be carried some distance from their original position and may then have the appearance of dykes. Such "sandstone dykes" are unaltered except for some secondary silicification.

In the area surveyed the Gondwana rocks with intrusive dolerites occupy the major portion of the ground between the main spread of the Deccan Trap lava flows and the alluvium of the Narbada valley and may be subdivided as follows:—

Upper Gondwana	Mahadeva .	Jabalpur. Bagra.
Lower Gondwana	Barakar. Talcher.	

The Jabalpur beds, when typically developed, consist of massive fine-grained sandstones alternating with layers of white clays. They often contain lenticles of conglomerate, earthy hæmatite, coal or carbonaceous shale. They have also yielded numerous fossil plants in a fair state of preservation. Mr. Crookshank's collection includes some 18 more or less identifiable fronds, a small leaf, which might be dicotyledonous, and two seeds. In collaboration with Dr. Cotter, Mr. Crookshank has determined the flora as a mixture of Rajmahal forms with coniferous plants of more recent age. These determinations render it possible that the rocks are a little older than

that portion of the Jabalpurs which has yielded the fossils previously obtained from this stage of the Gondwanas. The Jabalpur beds are much faulted, but are otherwise little disturbed. Underlying them is a sedimentary group, previously described as Denwa or Bagra, consisting of conglomerate, sandstone, and variegated clays. The absence of white clays and carbonaceous rocks is a rough criterion by which this stage may be separated from those above and below. Mr. Crookshank adopts the term 'Bagra' for the whole assemblage. The Bagras are often steeply folded and have been much faulted; their relations with the underlying and overlying rocks are unconformable, but this fact is obscured in the south of the area owing to the indefinite nature of the junctions. Plant remains are scarce in the Bagras and the only identifiable fossil discovered belongs to a typical upper Gondwana species. The underlying lower Gondwanas appearing at Mohpani have been described by previous observers, but, in addition, a small patch of Talchers was found near Nibhora (22° 46′ 30″ : 78° 59′) on the edge of the Narbada plain. The Gondwana rocks vary in thickness from 250 feet in the east to over 1,900 feet in the west of the area surveyed.

Lying along the southern edge of the Narbada alluvium and northern edge of the Satpuras from the Chhindwara-Narsinghpur road to Nibhora, and again from Khairi (22′ 44′ : 78° 44′) to the Dudhi river, is a band of Archæan rocks situated partly in the Chhindwara and partly in the Narsinghpur district, and resembling closely in structure and grade of metamorphism the Sausar series and associated rocks of the Sausar *tehsil* at the southern foot of the Satpura plateau. These metamorphic rocks may be divided into two main divisions, (1) biotite-gneisses and (2) a calcareous group comprising calcareous slates, dolomitic limestones, calcareous quartzites and calc-granulites. In addition, there are intrusive pegmatites and a few intrusions of epidiorite. These schists are folded, but are not well enough preserved for structures to be interpreted with safety. Mr. Crookshank notes the occurrence of certain types of rock deserving separate mention. Thus, in several places between Kishanpur (22° 48′ : 79° 9′) and Bandhi (22° 48′ : 79° 7′) near the boundary of limestone and gneiss, a peculiar pale-brown schist was found often sandwiched between bands of hornblende-schist and quartzite. Under the microscope this rock is seen to be composed largely of a pale-brown mineral with a little common hornblende. The brown mineral Mr. Crookshank identifies, on the basis of its optical properties,

as grünerite, the containing rock being, therefore a grünerite-schist. Another remarkable rock was found near Chamelikund (22° 47′ 30″ : 79° 7′) in association with calc-granulites. This was a coarsely crystalline rock composed of tremolite, grossular, leuchtenbergite and serpentine. The mineral to which the term leuchtenbergite is applied is a white chlorite recalling muscovite in outward appearance, with a refractory index of $1{\cdot}576 \pm {\cdot}002$, which is also the refractory index of penninite, leuchtenbergite belonging to the chlinochlore-penninite series.

Bhandara District; Central Provinces.

Sub-Assistant D. S. Bhattacharji continued the survey of the Bhandara sheet (55 O/12), whilst Dr. S. K. Chatterjee, on his attachment to the Central Provinces party, was allotted for survey the next sheet to the east (55 O/16). These two officers spent a month together mapping the common boundary of their two sheets and then separated for independent work.

During the period that it was possible to devote to field work, Mr. Bhattacharji mapped the country immediately to the south-east of Bhandara town on the east side of the Wainganga river. It was mentioned in the previous General Report that the boundary between the more metamorphosed type of country in which the Sausar series occurs and the less metamorphosed country referred to as the Bhandara belt of Dharwars (probably identical with the Chilpi Ghat series of the Balaghat district) traverses this sheet in a east-north-easterly direction. As already mentioned, the tract through which this boundary runs is largely obscured by alluvium, so that the precise relations of the two series of rocks are difficult to decipher. In this year's progress report, however, Mr. Bhattacharji points out that in addition to a general mineralogical differences between the corresponding rocks of the two belts, the characteristic Sausar types of calcareous, dolomitic, and manganiferous rocks are absent from the southern belt. No conclusive evidence concerning the relationship of these two belts has been found, but the rocks of the more crystalline northern belt show a south-south-easterly dip, whilst the rocks of the less metamorphosed southern belt show a north-north-westerly dip. It is suggested that these data indicate a synclinorium with a belt of disturbance along the axis of the synclinorium, in which, apparently, there is a tendency for the less metamorphosed rocks to the south to be thrust on to the more metamorphosed rocks to the north. On this interpretation it is possible that the less

metamorphosed rocks represent a higher section of the same succession of rocks, that is, an upward extension of the Sausar series. The differences between the two belts may be summarised as follows. The rocks of the more northern crystalline belt commonly contain felspar and biotite, but never show chlorite and rarely iron-ore, whilst in the rocks of the less metamorphosed tract of Bhandara chlorite is almost invariably present, iron-ore is common, biotite very rare and felspar completely absent. In the northern belt the intrusive rocks are felspathic, whilst in the southern belt the only intrusives are quartzose veins usually devoid of felspar. The rocks of the northern belt are characterised by epidotisation and the presence of bands of epidosite on approaching the boundary with the southern belt. The rocks of the southern or Bhandara belt described in Mr. Bhattacharji's progress report include: (1) muscovite-chlorite-schists (sometimes knotted), (2) quartzites of three types, (*a*) comparatively pure and massive, (*b*) chloritic, and (*c*) ferruginous; (3) red and yellow phyllites; (4) chlorite-schists.

During his work of the last two years, Mr. Bhattacharji has surveyed several sheets in the Nagpur and Bhandara districts and has mapped numerous faults often marked by fault-breccias. On tabulating these faults and also faults mapped by other officers in the Chhindwara and Nagpur districts he finds that they can be grouped into three divisions according to their direction. The faults of the first division have a strike ranging between E. 15° N.—W. 15° S. and N.—S., and are typified by the great Chhindoh fault in the Chhindwara district, mapped by Drs. Fermor and Fox some years ago, and by the smaller fault at Borgaon (21° 3′ : 79° 42′) in the area mapped by Mr. Bhattacharji in the field season under report, the Chhindoh fault lying in the more crystalline belt to the north and the Borgaon fault in the less metamorphosed Bhandara belt.

The faults of the second group range in direction between E. 10° S.—W. 10° N. and E. 70° S.—W. 70° N. and are found only in the more northern crystalline belt; they are typified by a fault at Paldongr in the Nagpur district.

The faults of the third group, of which only a few examples have yet been found, range in strike between N. 10° E.—S. 10° W. and N. 22° E.—S. 22° W., and occur only in the less metamorphosed Bhandara belt. Both the first and second groups of faults are divisible into chronological sections, namely, post- and pre-Trappean, according as they do or do not affect the overlying Deccan Trap.

Dr. S. K. Chatterjee commenced a survey of Sheet 55 O/16 (the Sakoli Sheet) lying to the east of the ground under survey by Mr. D. S. Bhattacharji, and including portions of the Bhandara, Sakoli and Gondia tehsils of the Bhandara district. As already mentioned, Dr. Chatterjee's field season was curtailed by illness, and he succeeded in mapping only the western and southern portions of this sheet. The rocks along the western margin comprise phyllites with quartzites and schists continuous with the bands mapped by Mr. Bhattacharji in the Bhandara belt of Dharwars. In the southern portions of this sheet near Pohra (21° 2' : 79° 51') and Girola (21° 2' : 79° 57') are found several occurrences of kyanitic rocks some of which were visited by Dr. Dunn during the course of his study of aluminous refractory materials. These rocks are described by Dr. Chatterjee as containing kyanite, tourmaline, muscovite, quartz and rutile with—at two localities, Mogra (21° 0': 79° 52½') and Girola—a mineral not hitherto reported from India, namely, dumortierite, which occurs abundantly as minute lath-shaped inclusions from 0·25 to 0·35 mm. long enclosed in practically every other ingredient. The mineral shows pleochroism from lilac to colourless. The occurrence of sillimanitic rocks is also reported. Should the compact kyanitic and sillimanitic rocks of India eventually prove to represent metamorphosed bauxitic clays as has been suggested by Dr. Dunn, we may have in these alumious occurrences of Bhandara another means of correlating the geology of the Central Provinces with that of Singhbhum and for this reason the careful mapping of the Sakoli sheet may be of some importance.

Coal-fields Party.

The detailed re-survey of the coal-fields of Jharia, Raniganj, Hutar, Auranga and part of the Rajmahal hills was continued under the supervision of Dr. C. S. Fox, Officiating Superintendent. The party included Messrs. G. V. Hobson, Sethu Rama Rau, E. R. Gee, A. K. Banerji and J. B. Auden. Dr. J. A. Dunn co-operated by re-surveying the Hutar and Auranga coal-fields in the normal progress of his work in the Palamau district. Dr. Dunn was supplied with new maps on the scale of 2 inches to the mile of the Hutar and Auranga coal-fields, and the mapping of the former and of much of the latter has been practically finished. It is hoped that the end of the present field season will see the completion of the examination of these two coal-fields. Mr. Hobson mapped an area roughly 100 square miles in the Bansloi valley of the Rajmahal hills on maps to the scale of one inch to the mile. Messrs. Sethu

Rama Rau, E. R. Gee, A. K. Banerji and J. B. Auden were fully occupied in the surveying of the Raniganj coal-field, which they have now completed. Dr. Fox was engaged in the remapping of the Jharia field which he had begun in the season, 1926-27. Except for the mapping of the Jharia-Bokaro field on the west side of the Jamunia river, the survey of the Jharia field on maps of a 4-inch scale has now been completed. The area to the west of the Jamunia will be completed early in the next field season.

In the survey of the Jharia coal-field—some 200 square miles—Dr. Fox has found considerable difficulty in adopting the sub-divisions of the Damuda series of the Raniganj field, the chief difficulty being the recognition of the so-called Ironstone Shale stage. He finds the simplest and clearest subdivisions in the Jharia field to be as follows :—

Damuda series . .	Raniganj (or upper coal-measure) stage.	
	Barren or Middle stage	Upper sandstones.
		Lower carbonaceous shales.
	Barakar stage.	Middle coal-measures (X-seam upwards.)
		Lower coal-measures (IX-seam downwards.)
Talchir series.		

The sub-division of the Barakars is taken from the top of No. IX-seam. The coals of the lower seams are in many ways different from those of No. X-seam upwards. At first sight the duller coals of the lower seams—from No. IX downwards—is very suggestive of the coal of the Karharbari seam in Giridih, but the fossil evidence does not justify the introduction of a Karharbari stage in the Jharia field. There is a steady increase in the percentage of volatile matter in the coal of the Damuda series in the Jharia field from the lower to the upper coal-measures. There is also an increase in the percentage of moisture in the same direction.

The lowest seams—from No. VI downwards—appear to thin towards the east when the seams are traced across the field. No. IX-seam, which is well developed in the east, passes into carbonaceous shale in the west. From X-seam upwards (*i.e.*, the middle coal-measures) there is a general tendency for the respective seams to split up towards the west and also to become poorer in quality when traced in the same direction. There is also a general thickening of the measures as a whole towards the west. The evidence, including the greater prevalence of coarser sediment, is suggestive that, for the middle (Barakar) coal measures at least, the streams or

rivers depositing the beds flowed eastward. The data support the idea that the vegetable matter was also deposited as sediment, and that this vegetable matter was firmly compacted before the next succeeding layer of sediment, usually a sandstone, was deposited on it. It is difficult to say if the vegetable matter was already converted into coal before being covered up. This cannot be determined with certainty, but Dr. Fox favours the opinion that the conversion of plant material into coal took place very early in the deposition of each bed of the material.

The faulting of the strata has been found to be peculiar. In many cases a fault, usually of the strike variety, begins, attains a throw of three hundred feet and then dies away again, within a total length of from five to eight miles. No clear evidence is available in support of contemporaneous faulting. The faults are nevertheless old faults, and are earlier than the intrusions of so-called mica-peridotite and the dolerite dykes. These intrusions cut across or follow the lines of faulting without showing any evidence of having been sheared themselves. There is one case of a dyke of dolerite which clearly crosses the strike of a mica-peridotite. This is distinctly suggestive of the dolerite dyke being the younger intrusion. The actual contact of the two rocks is not seen, but Dr. Fox is of the opinion that the mica peridotites are older than the dolerites though the difference in age may not be very much. In the Jharia coal-field the dykes are younger than all other rocks, but the youngest of these is the Raniganj stage. No Panchet rocks are met with.

From data available in the Raniganj field it is certain that the dolerite dykes and mica-peridotites in that area are younger than the Panchet. In the Rajmahal hills the dolerite and basaltic lavas are interbedded with strata containing lower Jurassic plant fossils. There is little doubt that the dolerite and mica-peridotite dykes in the Raniganj, Jharia, Giridih and Deogarh coal-fields are related and of approximately the same geological age. On a basis of proximity it has been assumed that the dolerite dykes of the Damuda valley are of the same age as the basaltic lavas of the Rajmahal hills. Presumably, therefore, the mica-traps are a little older, Dr. Fox, however, draws attention to the fact that he has traced the Deccan Trap lavas (Upper Cretaceous) to a point seven miles north of Lohardaga, 40 miles west of Ranchi and overlooking the head of the Damuda valley. If, therefore, proximity be taken as a guide the dolerite dykes of the Karanpura, Bokaro, Jharia, and other coal-

fields might be regarded as of Deccan Trap age. The lithological characters of the dolerite dykes are considered by Dr. Fox as being of the Deccan Trap facies.

The dolerite dykes have done very little harm to the coal-seams. The mica-peridotites on the other hand have damaged considerable quantities of coal. These "pests of our Indian coal-fields," as they were called by Sir Thomas Holland, have in their upward escape invariably emerged or followed the coal-seams. They ramify in and about a coal-seam in veins, but never fail to render the whole of the coal in their vicinity useless for normal exploitation. The natural coke which has resulted from the presence of the molten material is known as "*jhama.*" Some of the *jhama* from good seams—*e.g.*, No. XIV—is of excellent quality, but owing to the lack of cleat and to the hardness it is unprofitable to extract this natural coke at present market prices. Dr. Fox calls attention to the percentage of volatile matter in the natural coke at and close to the junction with the peridotites; in most cases there is from 6 to 9 per cent. only an inch or so from the intrusive.

To make a coke of this composition requires a temperature of about 500° C. It is to be concluded, therefore, that the dykes of mica-peridotite could not have been at a very much higher temperature than 500° C. Dr. Fox attributes the lowness of the melting point of the original magma from which these intrusions came to the flux-like action of the water which was contained in it as super-heated steam.

Dr. Fox has found himself in general agreement with the correlation of the coal-seams as finally fixed by Mr. R. R. Simpson. Although the survey of the two principal coal-fields of Raniganj are almost complete it will be some months before the reproduced geological maps will be available.

Considerable attention is being devoted to the estimation of the reserves of various classes of coal in the Jharia field. The calculations are to some extent complicated by the irregular way in which seams have been coked by igneous intrusions; by the manner of faulting; by the known change in the quality of some of the seams as they are traced across the field; and by the depth to which coal can be profitably worked in the Jharia field. Furthermore, in making allowances for loss in working and losses by fires and subsidence, the percentage to be arrived at depends on the mode of working in vogue. It is an open question whether the existing methods of work-

ing are always the best and most economical. Serious losses are said to have occurred in depillaring operations—so much so that some engineers are afraid to depillar, with the result that 125 million tons of coal are at present standing in pillars. Methods of working have also been affected by the recent depressed state of the coal market. It has been stated that sand-stowing is the only satisfactory solution to the wastage problem in coal mining in India, and yet the method has under present conditions been found to be too expensive to adopt, and those collieries which had installed sand-stowing have been obliged to discontinue the practice for the time being. For these reasons therefore, any figure of *available* reserves of coal, with conditions as they now are, must not be allowed to give a false idea of security.

In the higher ground in the extreme northern part of Sheet 13 of the Raniganj field Mr. Gee observed the Ironstone Shales, usually in tank excavations near the villages of Jamsol and Bhaterdaha. To the south, over the greater part of the area, the middle and lower strata of the Raniganj series exist, but are usually hidden by a capping of laterite and alluvium. In the southwestern portion of the sheet the massive false-bedded sandstones of this series crop out in the lower ground. The demarcation of the coal-seams and the geological structure of the area, therefore, depend largely on the information obtained from colliery workings and boring records. Using these data a correlation of the coal-seams has been attempted. Three large cross-faults following a southeasterly to south-south-easterly trend, and downthrowing to the southwest, intersect the area, and two main strike-faults following a west south-westerly direction and downthrowing to the north-north-west repeat the strata in the southeastern part of the sheet. A similar fault complicates the seams to the east of Jote Janaki.

The dip in the eastern part of the field being at a gentle angle to the southeast, the upper portion of the Raniganj series crops out over a large part of Sheet 19, to the south of Sheet 18. Sheet 19 embraces the Raniganj, Kajora and Dakshinkhanda areas and continues south to the Damuda river. Laterite again caps the Raniganj rocks in the northwestern part of this sheet, while the greater part of the east and southeast is covered by alluvium. In the southeastern corner of the area, however, west and southwest of the village of Dubchururia, definite Panchet beds crop out. These include the typical red clays and massive soft micaceous

yellow sandstones of the middle Panchets. This southern portion of the coalfield approaching the southern boundary fault, appears to be much faulted, and although a fair idea of the structure and correlation of the seams has been worked out in the Kajora and Raniganj localities, the paucity of sections and boring information in the intervening tracts leaves one in doubt as to the exact horizons exposed in these areas. No dolerite intrusions were observed within Sheets 18 and 19, though a number of thin dykes of mica-peridotite type were met with. This eastern portion of the field, however, appears to be less affected by these intrusions than is the case with certain areas to the west.

A fairly satisfactory correlation of the coal-seams of the Raniganj series had been arrived at in the areas previously examined. In these areas—the middle and western portions of the coalfield—it was observed that the important coal-seams persist over considerable distances, but that they are liable to change in quality and in thickness, in some cases quite rapidly. In the extreme east of Sheet 13 some of the lowest seams have thinned, the Poniati seam to 4 feet, and the Koiti to a thin seam of no present economic value. The Taltor seam, about 120 to 150 feet below the Poniati is, however, fairly constant, about 4½ feet thick and of quite good quality. Of the middle Raniganj seams the Poriarpur-Satgram seam is the most important, and has thickened to over 13 feet at Satgram. The upper Raniganj coal-seams are, however, very constant both in quality and thickness. Of these the upper seam—the Ghusick-Siarsol seam—is about 19 feet thick, the upper part being the better quality, while about 180 to 200 feet below this seam is the 21-foot Nega-Raniganj seam, the middle and lower portions of which are of better quality. Beneath the Raniganj seam, separated from it by strata about 80 to 100 feet thick, is a 9-foot seam, the Narankuri seam of the Egara area. Further east, in Sheets 18 and 19, these three seams continue, the lowest increasing in thickness up to 13 feet; they are worked in the Babuisol and Kajora areas west of the faults which run a short distance west of the Andal-Sainthia Chord line. To the east of this fault to the north-north-east of Kajora village, the section according to Mr. Gee, is as follows :—

Sandstones, shaly sandstones and shales including several thin seams of coal.

20-foot (Upper Kajora) seam.

Massive sandstones, about 140 to 160 feet.

Coal-seam, 35-40 feet thick, with shale and shaly sandstone partings.

The evidence definitely points to the two lower seams having run together, forming the Jambad seam to the north and the Bowlah seam to the north-east.

From 500 to 600 feet below these seams in the western parts of Sheets 18 and 19, is the Toposi-Kenda seam, about 27 feet thick in the west and increasing to 30 feet in the Kenda area. Mr. Gee correlates this seam with the Poriarpur-Satgram seam of the middle part of the field. A fault, down-throwing to the west to the extent of 150 to 200 feet, intervenes east of Satgram, and east of this place as far as Tapasi, a distance of about 1½ miles, the ground over which this seam must crop out has not been proved. It is significant that the lower Raniganj series in the eastern part of this field, is considerably thinner than to the west, the suggestion being that during a part of the time when these thick seams of the east were being deposited, arenaceous sediments were being laid down to the west.

Beneath the Toposi-Kenda seam, which continues to the east, about 25 feet thick, as the Chora seam and is separated from it by about 150 to 200 feet of strata, is the Jote Janaki seam, about 11 feet thick in the west, thickening to 18 feet in the east. Mr. Gee remarks that this seam occurs at the horizon of one of the unimportant coal-seams which are met with between the Poriarpur and Koiti seams of the middle portion of the field. From 300 to 400 feet below this Dobrana seam is a group of 3 coal-seams met within the area just south of Chichuria and near Dhasala. At Chichuria these seams include an uppermost 8-foot seam, a middle 5-foot seam, and a lower 2-foot seam. The Ironstone Shales are encountered about 400 feet beneath this group of coal-seams, which apparently occur about the horizon of the Koiti-Poniati-Taltor group of Sheet 13. It is suggested that the 21-foot seam of Purushottampur in the eastern part of the field is the equivalent of the Chora seam, and the Samla-Govindpur seam, which crops out some distance to the north as a result of faulting, is the continuation of the Dobrano-Jote Janaki seam.

Within Sheets 18 and 19 the laterite up to about 8 feet in thickness is often seen to rest on Raniganj sandstones. East of this area an apparently more recent series of ferruginous brown and red sandstones, with reddish and white clay intercalations, intervenes between

the coal-bearing series and the laterite. The red clay bands suggest a Panchet horizon for these newer beds, but the sandstones are very distinct from the Panchet types met with in the Hirapur area of Sheet 9, and appear to resemble some of the Mahadeva specimens, while the presence of the white and yellow clays with ironstone concretions, well observed at Durgapur, also indicates a possible Upper Gondwana age. So far there is no palæontological evidence to assist in fixing the horizon of these sediments. In the eastern part of the field yellowish gravel of well-rounded white quartzite pebbles, in a sandy matrix, is seen to underlie the laterite. The gravel bed is often several feet thick and appears to pass up gradually into the pebbly laterite of this eastern area. In this part of the field large boulders of the ferruginous sandstone, exactly similar to the type above-mentioned, occur in the laterite, together with numerous small fragments of ironstone. The laterite of Sheets 18 and 19 is of a purer variety than that found further east; it includes numerous fragments of quartz geodes suggesting a trappean origin, also a number of well-rounded pebbles of white and yellow quartzite. Some of the laterite appears to be secondary, though probably not transported from any great distance.

Mr. Gee remarks that the junction of the Lower Gondwanas and the Crystallines of these areas is definitely a line of natural deposition. To the north of Panuria the Talchirs rest on the Crystallines, but the group is much thinner than to the west, and continues to diminish in thickness rapidly when traced to the southeast into Sheet 11, so that to the north of Kantapahari and Jamgram the basal pebble-bearing beds of the Barakars have been deposited directly on the Crystallines. This basal pebbly sandstone remains fairly constant, though often very thin, in the faulted area to the north of Sarshatali and again across the Adjai in the Pariarpur-Arang area. In the Panuria area these pebbly sandstones are followed by a series of coarse sandstones with some shale and fire-clay bands, above which is a thick seam of carbonaceous shale and shaly coal, representing the easterly continuation of the Alkusha thick seam. This seam continues to deteriorate to the east and is represented in the Churulia and trans-Adjai areas only by carbonaceous and grey shales and fireclays. Above this inferior seam are thick massive sandstones in which occurs the main coal-seam of these areas, the Gourangdi-Jamgram seam. Mr. Gee finds good reason to correlate this seam with the Churulia and the Pariarpue-Kasta-Arang seam. About 20

feet thick at Gourangdi, it thickens to 30 feet to the east. Traced further southeast beyond Karabad the seam deteriorates in quality, the upper and middle portions becoming shaly. A second seam about 15 feet thick has also been worked in the past around Kantapahari, but is of poor quality and apparently passes into shale to the east. A 4½-foot seam which has also been worked in this western area has not been met with east of Kapistha. It appears that the Barakars, as a series, are considerably thinner in these eastern sections, especially around Churulia, than in the middle and western parts of the coalfield.

Rao Bahadur Sethu Rama Rau extended his work beyond the eastern limits of the Raniganj field to the area about Mulliahara, where sandstones and shales very like those of the Raniganj stage occur. This tract was originally thought to be covered by alluvium so that the discovery is of some interest. It is known that the Gondwana strata of the Raniganj coal-field occur under the alluvium towards Burdwan, but the laterite and other overlying strata were thought to be present in considerable thickness and the depth to the coal—if existent—too great to make exploitation attractive. According to Mr. Sethu Rama Rau the sandstones of the railway cutting west of Durgapur belong to the Panchet and not to the Mahadeva series; similarly the rocks on the Singaran Nala east of Ondal are considered by him to be Panchets, and the strata about Jamua, which were thought to be Panchet he now regards as belonging to the Raniganj stage.

These observations as a whole would make the thickness of the unproductive strata less than was supposed, and, if coal does occur below, the seams may not be at unworkable depths. Dr. C. S. Fox and Mr. E. R. Gee, however, are not in full agreement with these views, and suspect that the coal seams would be found at too great a depth to work for many years to come. Evidence from the Adjai valley in the area examined by Mr. Auden shows that the Barakar coal-seams have been reduced to such a condition that they are unattractive, but this is partly due to over-lap. It is therefore possible that the Barakar coal-measures may be attractively rich in coal to the dip and further east. Above the Barakars and therefore still nearer the surface are the Raniganj stage coal-measures. These have been proved up to Purshottampur, where Messrs. Tata & Sons sank pits and equipped a colliery on the most up-to-date lines. This colliery is on the market for sale as the

quality of the coal is not suitable for the manufacture of metallurgical coke but is that of a good domestic fuel.

Towards the end of the season, at the instigation of Dr. Fox —who had heard of a discovery of coal in the Manbhum district south of the Jharia coal-field—Rao Bahadur Sethu Rama Rau visited Bhojudih on the Bengal Nagpur Railway, and from there extended his enquiries to Chandankiari and Dhobra. He found that the rocks exposed in the areas he examined were hornblende and biotite gneisses, and it is his opinion that the reputed discovery of coal relates to one or other of these dark coloured gneisses in a particularly dark band. The villagers were unable to give any information. While at Bhojudih Mr. Rau asked permission to examine the southern boundary of the Jharia coal-field in order to study the nature of the faulting. He had found in the Raniganj field the Gondwana strata in the vicinity of the southern fault thrown into a series of domes and basins. The same is true of the Jharia southern boundary, but on a smaller and more contorted scale.

The formations present in the Raniganj areas examined by Mr. Auden include metamorphic rocks of Dharwar age, the Barakar, Ironstone Shale and Raniganj stages in the Damuda series, intrusive lamprophyre and dolerite, and laterite. The only two seams of importance are the Kasta seam in the Barakar stage and the Samla seam in the Raniganj stage. The Kasta seam is found as far east as Rasuan after which it dies out, probably by overlap. It is also found in the west of the Hingla field, where it is of poor quality. The seam is of variable thickness, at its outcrop being seldom over 13 feet thick, while to the dip it may be as great as 28 feet. No sign of coal has been found in Sheet 21. The Samla seam terminates westwards against the Adjai monoclinal fold-fault, and is divided further east, near Chatrisganda, into two outcrops about a mile apart by a fault with at least 400 feet throw. It is also interrupted by strike faults at Kendra and Baidyanathpur. Mr. Auden remarks that on account of the pitching syncline which closes towards Bhuri, the possibility of changes in strike and dip should be considered in the event of exploitation to the west of the Samla property.

Mr. Auden shows that the main structural feature of the district is the Adjai monocline, with minor parallel folds and faults. The junction of the Barakars with the metamorphic rocks at the crest of the Adjai fold is accompanied by considerable crush effects, as at Churulia. He believes that the Barakars have overlapped the

Talchirs and lie with a junction of deposition on the metamorphic rocks, incorporating the pegmatitic and schistose materials of the floor. Accompanied with this overlap is a gradual decrease in thickness of the Barakars eastwards and a change in lithology. The association together of fireclay, massive arkose grit and Kasta coal is continuous throughout the area where coal is found. To the east, after the dying out of the coal, the arkose facies persists in a reduced form and ironstones become more important; at Panshuri and Pajera these ironstones are oolitic.

On account of its straight south-western boundary the Hingla field had been assumed by some to terminate here in a boundary fault; Mr. Auden, however, failed to find evidence of such a fault. He believes that the outliers owe their isolation to denudation of the crests of shallow folds and to preservation in irregularities of the floor of deposition. According to this view the outliers should be regarded as connecting links with the larger outliers of Suri and the Rajmahal hills, and not as fault outliers.

Mr. Auden found many outcrops of fresh olivine-bronzite-dolerite which may be correlated with the "Newer Dolerites" of Dr. Dunn, belonging to the Dharwars. These dolerites shew excellent examples of metamorphism to hornblende schists and amphibolites. Every stage between unaltered dolerite and hornblende schist may be observed, by the gradual loss of ophitic structure and replacement of pyroxene by amphibole. The metamorphism is due perhaps to the later intrusions of granite (rarely seen) and connected pegmatites and quartz veins which are abundant. The latter are occasionally found to cut the amphibolites and hornblende schists.

Mr. A. K. Banerji continued his mapping to the extreme eastern limits of the visible Gondwana rocks of the Raniganj coal-field, where exposures of rock are remarkably few. Most of this area (east of Purshottampur and north of Durgapur) is covered by spreads of alluvium relieved by laterite, while a soft, coarse sandstone forms the higher ridges and swells of the land. No fossils have been found in these sandstones, but they have a Panchet aspect. There is no valid reason, however, for disagreeing with W. T. Blanford's opinion, and they are regarded as the equivalents of the beds which cap Panchet hill (Dubrajpurs).

Mr. Banerji has in several places found unrounded fragments of silicified wood in association with the covering laterite but often loose on the sandstone below. It was thought that this fossil-wood

had weathered out of the sandstone. Before any palæontological determination was made it was thought the fossil wood might be the same as that from the Asansol railway cutting. A complete examination of it has not yet been made, but the preliminary determination is that the wood is not that of *Dadoxylon* and that it has the characteristics of dicotyledonous wood.

The laterite contains broken fragments of quartz and chalcedonic geodes of trappean origin ; this strongly suggests the view that the laterite is detrital and has been derived from the primary laterite of western Chota Nagpur traced to the north of Lohardaga by Dr. Fox. Accompanying the laterite there is a conglomeratic and sandy older alluvium. It is in association with this material that the fossil-wood is generally found. Mr. E. R. Gee and Dr. Fox are both of the opinion that the fossil-wood definitely comes from this older alluvium as suggested by Dr. Cotter when he made a provisional determination of the wood. The fossil-wood may, therefore, be in no way connected with the underlying sandstones whose precise age is still uncertain. This evidence, such as it is, is against the prospects of getting workable coal at a small depth in this region. Any attempt at proving coal here and beyond the visible limits of the Raniganj coal-field must also be carried out in face of the record of the Durgapur boring, in which the total depth reached was 3,000 feet without striking coal.

Pachwara, Rajmahal Hills.

Mr. G. V. Hobson was, on his return from leave, attached to the Coal-fields Party and deputed to re-map an area of about one hundred square miles in the upper Bansloi valley of the Rajmahal Hills. This area includes the little coal-field of Pachwara. The types of rock met with were :—Archæan gneisses ; coal-bearing Damuda sandstones ; the Dubrajpur beds ; the Rajmahal traps and associated intertrappean plant beds ; Laterite and Alluvium. No Talchir shales or boulder beds were encountered, the younger strata overlapping each other when traced westward. A pre-Gondwana ridge of metamorphic rocks occurs along the west of the southern part of the Rajmahal Hills.

The Pachwara coal-field is worked in several places, but chiefly at present about Bargo and Sakalma where seams of 6 to 8 feet occur. The seams have not been correlated but it is quite likely that the main seam in each place is the same. The output from the quarries of Bargo and the pits of Sakalma is small and irregular. The coal has a local sale only being largely of the quality used for burning

bricks. It is a long-flaming, non-coking coal of a remarkably well-banded character. Some of the very bright bands (vitrain) are as much as an inch in thickness.

Mr. Hobson made an interesting discovery of specimens of *Unio* in the overlying Dubrajpur beds and has thus established their relationship with the Rajmahal series in spite of the close resemblance of the Dubrajpur and Damuda sandstones. The fossil evidence further shows that there is a marked palæontological " break " between the Damudas and the Dubrajpur beds. The Dubrajpur beds are, so to speak, infra-Trappean to the Rajmahal volcanic series. The Dubrajpur beds are consequently provisionally taken as the equivalents of the sandstones which cap Panchet hill in the Raniganj coal-field and Lugu hill in the Bokaro coal-field. They are also possibly the equivalents of the Athgarh sandstones of Cuttack. Their age may be assumed as approximately Rhætic to lower Lias, and for this reason may be close in age to the reptilian beds of Tiki in south Rewa and the Maleri stage of the Godavari valley.

Mr. Hobson evinces no doubt that the basalts of the Rajmahal series are lava flows. He has mapped and separated ten distinct flows averaging 60 or 70 feet in thickness. The Rajmahal plant-bearing beds occupy an inter-trappean position to the flows of the lower part of the series only. No fossils have been found in the upper inter-trappeans. The thickness of these sedimentary beds is small in comparison with the thickness of the lavas. The age of the Rajmahal plant beds has been accepted as Lias to lower Oolite, but in the absence of fossil evidence it is impossible to give a precise age to the topmost lavas. Mr. Hobson has noted a few dolerite dykes in associated with the lavas, and has drawn attention to the faulted condition of the Rajmahal series. He remarks on the similarity of the Rajmahal and Deccan traps petrologically, and emphasizes the dissimilarity between the Rajmahal and Sylhet traps.

Dr. Fox remarks that the work of the Coal-fields Party as a whole points to some kind of genetic relationship between the Rajmahal traps, the dolerite dykes of the Damuda valley coal-fields and the Deccan trap outliers of western Chota Nagpur. Nevertheless it is to be remembered that the lowest Rajmahal traps cannot (palæontologically) be younger than lower Oolite and that the Deccan Trap of the Narbada valley is not older than middle Cretaceous.

Overlying the trap of the Rajmahal series are spreads of laterite which in turn are covered eastward by recent alluvium. Mr. Hobson

has dealt at some length with the question of local water supply.

Dr. Fox visited and checked the old mapping in the Daltonganj coal-field and was of the opinion that this area can be re-surveyed in detail in the normal survey of the Palamau district. The Bengal Coal Company have been operating in this field for many years and the information they have obtained does not alter the opinions previously formed as to its value. Mr. A. K. Banerjee made an unsuccessful search for marine fossils in the basal beds of the coal-measures in the Rajhara area of the Daltonganj field. Both Dr. Fox and Mr. A. K. Banerji are of the opinion that in spite of the Karharbari character of the flora in the basal beds of the coal-measures near Rajhara these beds are separable on lithological grounds from the underlying Talchirs which are unfossiliferous.

Hutar Coal-field.

Mining operations in the Hutar coal-field at the time of Dr. Dunn's visit were at a standstill and Dr. Dunn found it difficult to make an estimate of the coal reserves in this field. Some of the coal is of good quality but the faulted nature of the strata renders it difficult to make any reliable estimates. There are two or three seams which may be worth exploitation when railway communication is established but with the coal trade as it is, the Hutar field is not likely to be of immediate importance. In the case of the Auranga coal-field although considerable quantities of coal are known to exist the quality of the samples so far tested has been consistently low.

Dr. Dunn recognised an overlap of the Upper Gondwana (Mahadeva) on the Panchet and on to older stages of the Damudas when the beds are traced towards the west. In the Auranga field be found evidence of the existence of the Panchet series above the Damuda. In the Hutar field the Mahadevas appear to rest directly on the Barakar stage. In both fields there is evidence of overlap of the Barakars on to the Talchirs in some places and perfect conformability in some sections.

In the case of the Hutar field, west of the Koel river the Talchirs and Barakars close to the northern boundary of the basin are much faulted, the several faults forming branches of the fault movement which let down the beds in this part of the coal-field. This faulting

increases to such an extent to the west that the Barakars eventually have been cut off completely and the Mahadevas abut against the Archæans.

In the Deori Nadi section of the field, Dr. Dunn reports, the coal seams occur in a zone from 80 to 200 feet above the base of the Barakars, but there is an additional thin seam about 320 feet above the base. The seams thin out to the south and east. There are two main seams, 110 feet and 150 feet, respectively, above the base of the series ; of these the lower seam is the more persistent and is of a better class coal. In the Hutar-Sindharao section of the coal-field there are three fairly persistent seams, of which the middle seam alone is of reasonable thickness (up to 6 feet). The lower seam is high in ash, and both of the higher seams in places also have a high ash content. In the Nawadih-Bijka section there is at least one main seam from 4 to 11 feet in thickness and of first class quality in places overlying which are apparently other impersistent seams of coaly shale. The outcrops of these seams have been repeated several times by faults.

Auranga Coal-field.

The Auranga field is bounded usually by faults, some of which must have a throw of several hundred feet. In the vicinity of Kumandi the throw of the faults on the north and south side of the Gondwanas is sufficient to cut out the Talchirs and almost the whole thickness of Barakars, and to bring the Mahadevas almost in contact with the Archæans. In contrast to the usual gentle dips found in the majority of coal-fields in India, the dips in the Auranga field are characteristically high, averaging about 40°. The Talchirs, as elsewhere in India, form the basal series of the Gondwanas. North of Latehar the only known carbonaceous bed in the Talchirs of the Auranga and Hutar fields crops out.

Most of the coal seams occur in the Barakars, although there are some thin seams in the Raniganj stage. With the few exceptions S. E. of Jagaldaga, the seams observed were thin bands of poor shaly coal. East of Jagaldaga there is a seam 40 feet thick with minor underlying seams from 3 to 9 feet thick ; these, however, consist largely of carbonaceous shale and the proportion of coal across the width of the 40-foot seam, according to Dr. Dunn, is not high. The coal in fact is patchy and none of it seems to be of good quality ; the ash and water contents are high and the coal breaks up on handling.

Several traverses were made in the North Arcot district of Madras by Rao Bahadur M. Vinayak Rao to discover the extent of the charnockites and the younger gneisses. The following sheets were partly mapped with the help of Sub-Assistant A. K. Dey: 57 P/5, L/2 and L/3. The charnockites, which are extensively developed near Vellore south of the Palar, become less prominent to the east, where they die out west of Arcot except for a few thin dykes running in a north and south direction. A band of decomposed charnockite was found near Arkonam.

North Arcot district, Madras.

To the south-west of Arcot norites, which have the appearance of Dharwar hornblende schists, are found intruding into the gneisses forming high hills south of Pusimalai Kuppam bungalow in the Arni *jaghir*. To the west of this the charnockites are found alternating with the newer gneisses and granites. The series mostly developed in this area is that of the older gneisses, which are highly garnetiferous in the neighbourhood of the charnockites. The newer gneisses are mostly hornblendic, and in places approach a syenite. The Jalaipet *massif* gives off a number of dykes of a basic nature which stretch in an east and west direction. Hornblende granites and gneisses are extensively developed in the area near Tirupattur and are found near Tiruvannamalai as far as the borders of the South Arcot district. East and west dykes are found north of the Palar river intruding into the older Dharwars and the newer granites.

At Melpatti, a railway station between Ambur and Katpadi, the hill north of the village shows a peculiar assemblage of rocks which appear to pass from one into the other without any appreciable change. Hornblende granites, granites with pink felspar and a grey gneiss, are found in the same hill. North of Walajah Road railway station quartz schists are found extensively developed in a hill north of the railway line. In places the colour of the rock is greenish, and pegmatites are found.

Dr. G. de P. Cotter resumed charge of the Punjab Party and, during the months of December and January, was occupied in mapping Sheets 43 C/12 and 43 D/9. This area lies in the Potwar plateau, and is a westward continuation of that mapped by Mr. D. N. Wadia in season 1925-26 and previous seasons (See *Mem. Geol. Sur. Ind.*,

Potwar Plateau, Punjab.

LI, pt. 2). The entire area is covered by Siwaliks and alluvium, except in the extreme south of Sheet 43 D/9, where, near Kalar Kahar, the basal Siwaliks (Kamlial stage) rest upon the Nummulitics without any noticeable discordance, but with a want of conformity which is represented by a basal conglomerate in which rolled nummulites, derived from the Nummulitic series below, occur as pebbles. At Kalar Kahar, E. S. E. of the Rest House, there is an interesting occurrence of red marly beds resembling the Salt Marl of the Salt Range. The marl has been noticed by Wynne, who identified it with the Salt Marl (*Mem. Geol. Sur. Ind.*, XIV, p. 182), and by LaTouche (*Rec. Geol. Sur. Ind.*, XL, p. 46) who put forward doubtfully the suggestion that it might be of secondary origin. The marl is intimately associated with travertine and occurs along the north slope of the Kalar Kahar hill, where there are also numerous warm springs of mineralised water containing a little hydrogen sulphide in solution. Dr. Cotter is inclined to agree with Mr. LaTouche's suggestion that the red marly beds exposed here are a secondary deposit.

The examination of the Siwaliks did not produce any fresh results. The whole series is well represented from the Kamlial stage upwards to the Upper Siwaliks. The base of the Upper Siwaliks near Nila and Hasal in Sheet 43 C/12 is marked by conglomerates. It is interesting to note that a specimen of *Dinotherium* was collected north of Nila from conglomerates which are apparently in the basal zone of the Upper Siwaliks. This may indicate that the local base of the Upper Siwaliks in this area reaches downwards into the Dhok Pathan zone, although elsewhere it appears to be of Tatrot age. It may be recalled that the base of the Irrawadian series in Burma also varies similarly in age.

In early February, Dr. Cotter paid a brief visit to the Khaur Oilfield. Dr. Cotter would prefer to incorporate the "Crest Sandstone," which is grouped with the Murree Beds in Sir Edwin Pascoe's memoir (*Mem. Geol. Sur. Ind.*, XL, Plate 78A) with the Kamlials as their basal member.

In the second half of February, Dr. Cotter in company with Dr. F. R. Cowper Reed and Mr. H. M. Lahiri, made a close examination of the section exposed at Warcha Salt-Mine and in the Jarhanwala and Jansukh *nalas* through the Salt Marl and Purple Sandstones to the top of the Productus Limestone. With the Salt Marl is associated a series of shales which on heating with a match

emit the characteristic smell of oil-shale. They are evidently of a low grade and of no commercial importance. With them are interbedded cherty siliceous layers and green sandy beds. This oil-shale series, as it may be called, is sharply folded into miniature anticlines and synclines, and in some sections appears to be interbedded with the Salt Marl, but it is possible that this is deceptive, and that they really underlie the Marl, or at least are stratigraphically separate from it.

Above the Salt Marl, there is exposed in the Jansukh and Jarhanwala section a Purple Sandstone group, which Dr. Cotter regards as identical with the Purple Sandstone of the Salt Range described by Wynne and others. Dr. Reed is somewhat doubtful of this correlation and has suggested that it may be of later age. The group is 260 feet thick in the Jansukh Nala, but is reduced to 105 feet in the Jarhanwala, by the removal of the basal beds probably by thrusting, as the shattered condition of the basal sandstones in the Jarhanwala suggests.

Both in the Jansukh and the Jarhanwala, the Talchir Boulder Bed was found lying upon and strongly adherent to the Purple Sandstones. In the Jansukh, the thickness of the Boulder Bed varies from 6 inches to 2 feet. In the Jarhanwala, the basal bed of the Speckled Sandstone group (the group above the Purple Sandstones) contains numerous boulders, but there is no definite boulder-bed, and the boulders are somewhat scattered.

The boulders of the Boulder-bed fall into two groups, (1) graphic granites, and (2) rhyolites and porphyries. Mr. A. L. Coulson, who examined the specimens, regards the granites as closely resembling the granites of Sirohi State, Rajputana, and the Jalor granite described by LaTouche (*Mem. Geol. Sur. Ind.*, XXXV, p. 91). The rhyolites and porphyries may perhaps be compared with the Malani rhyolites.

Above the boulder-bed, the Speckled Sandstone, in the Jansukh Nala, has a thickness of 384 feet. Towards the base are fine-grained green sandstones with coaly laminæ and indistinct plant remains. Near the top is a well recognisable zone of Lavender Clays. This group passes conformably up into the Productus Limestone. The section through the Productus Limestone was carefully measured in the Jarhanwala Nala.

The total thickness of the Productus Limestone Dr. Cotter reports to be about 800 feet, of which the lower 501 feet are exposed in

the Jarhanwala, and the upper 300 feet upon the hill-slopes above the Jarhanwala. The first 225 feet, counting from the base upwards, can be subdivided lithologically into small units owing to the alternation from limestone to shale and sandstone. Above this, the beds assume a much more homogeneous aspect, and no longer admit of minute subdivision, although the limestones grow markedly sandy as higher horizons are reached. The basal 100 feet are characterised by *Fusulina*. About 160 feet from the base there is a bed of carbonaceous shale with plant remains, including *Gangamopteris* and *Glossopteris*. Immediately above this is a pipe-rock which, owing to its peculiar character, forms an easily recognised horizon and is of use in correlating this section with others on the hill-slopes adjacent.

The topmost 100 feet of the Productus Limestone are full of cephalopods (*Pseudosageceras*, *Meekoceras*, *Aspedites*, *Flemingites* and *Ophiceras*) of Lower Triassic age. A large collection was made from various horizons through the whole series, which is at almost all horizons fossiliferous and rich in brachiopods. This collection has been sent to the Sedgwick Museum, Cambridge, where it is being studied by Dr. F. R. C. Reed. A joint paper by Drs. Reed and Cotter, and Mr. Lahiri, giving the results of their examination, will shortly appear in the *Records*.

North Punjab and Kashmir.

Mr. Wadia spent the whole of the field-season in working on the syntaxial belt of the N. W. Himalaya, along which the various converging fold-axes of N. E. Hazara meet those from the N. W. part of Kashmir. The main object of this survey was the continuation of the mapping of the Pir Panjal range in a north-west direction and a study of the relations of these formations, across the Jhelum and the Kishenganga, to those of Hazara. Broadly stated, the results obtained so far show that the various rock-zones of the south-western flank of the Pir Panjal continue N. W. along an unswerving strike to within a few miles of Khagan. At this point the Himalayan strike swings completely round, and the same belt, with greatly altered thicknesses of the constituent formations, but without material change in their stratigraphy or tectonics, descends on a N.—S. strike towards Garhi Habibullah, whence onwards the belt loses its identity and merges itself in the more expansive Hazara basin of sediments.

Detailed lithological examination of the Slate zone in north-east Hazara reveals the existence of three distinct constituents. The largest component is a finely cleaved and foliated argillaceous and chloritic slate indistinguishable from the Dogra Slate of the Pir Panjal, which constitutes an important substratum of its southwestern side along its entire length. The two slate belts meet in Khagan. The second easily distinguished unit is composed of black argillites with arenaceous strata, copiously current-marked and false-bedded and but imperfectly cleaved. The cleavage is often absent and the rock breaks in large angular fragments with conchoidal or even fracture. These rocks, to which the term "slate" can only be applied by widely stretching the significance of this rock-name, are obviously a group of younger sediments resting as outliers on the Dogra Slate. The third constituent is represented by a thick group of light-coloured quartzites and arenaceous metamorphosed sediments, overlying the Slates with a great unconformity, and denoted by a thick, coarse, basal conglomerate. The frequent alternation from phyllites to quartzites, and the constant presence of false-bedding, ripple-marks and colour-banding in these sediments point to estuarine if not to flood-plain deposition and, from the fact that an exactly similar assemblage of rock-elements in the Pir Panjal rests upon the Agglomeratic Slate series, containing fossil *Fenestellæ*, Mr. Wadia has provisionally referred this element to the Gondwana system.

The discovery of many well glaciated boulders and pebbles in the basal conglomerate of the Infra-Trias series leaves no doubt now regarding Mr. Middlemiss' suggestion of its homotaxial equivalence to the Talchir Boulder-bed. The overlying limestones have undergone silicification in a manner that has resulted in the production of massive, coarse, holocrystalline quartz-rock at some places and "quartzites" and oolitic flints at others, while in the Srikot mountains the whole series of limestones is replaced by enormous aggregates of granular and crumbling, if not actually pulverulent silica, containing angular pieces of yet unaltered limestone.

It is possible that the difficulty felt by Wynne in correlating these and similar rocks with the Infra-Trias, and which led to his giving them the new name of "Tanol series," arose from this extensive silicification and subsequent thermo-metamorphism (by gneissic intrusions) of the Infra-Trias limestones. As a result of Mr.

Wadia's observations this difficulty seems to disappear when the numerous comparatively unmetamorphosed sections in the areas to the west of the Jhelum are studied.

The enormous area of Eocene rocks shown in Lydekker's map, near Muzaffarabad, is in fact composed of complexly folded Infra-Trias, Trias and Eocene. The facies of Eocene rocks present here tends to bridge over the somewhat divergent facies of the Pir Panjal and Rawalpindi Nummulitics. A thick series of grey, finely-bedded limestones, closely associated with the Nummulitics, but totally unfossiliferous, has been referred to as Pre-Ranikot limestone. The Murrees of the Kishenganga Valley are reported as shewing some marked differences from Rawalpindi Murrees, in being predominantly shaly with many limestone intercalations. At some places Mr. Wadia found some difficulty in separating the basal Murrees from the Chharat shales underlying them, the passage being apparently transitional over some hundred feet of strata.

The monotonous complex of slates and slaty rocks, which form the whole district of Karnah, contains, to the S. E., a highly interesting development of older Palæozoic systems, resting normally in a compressed syncline in the Dogra Slate, which in turn has been found to contain inliers of still older Purana rocks. Thus some hazy yet noteworthy clue is furnished regarding the sequence from the older Purana to the Dogra Slate and from this to the Lower Palæozoic. The oldest rocks to be distinguished in the area occur in a series of tight anticlinal flexures in the isoclinally folded Dogra Slates, consisting of Carbonaceous slates and limestones, (Salkhala Slate), which show a remarkable petrological identity with the lately described Jutogh series constituting the oldest rocks of the Simla area. What are regarded as probably Ordovician and Silurian systems of strata, manifestly in conformable relation with the Dogra Slates, occur in the high peak of the Shamsh Abari in a conspicuous, easterly-pitching basin-fold. About 7,000 feet of grauwackes, sandy shales and limestones are found containing badly preserved corals, crinoids, brachiopods, etc., which show some affinities with the Silurian of Kashmir. These are succeeded by 2,000 feet of Muth Quartzites, followed by a great thickness of the Upper Carboniferous Panjal Volcanic series—agglomerates, ash-beds, and bedded Panjal Trap flows of the usual composition. A late snow-fall and bad weather conditions interfered with field-

work in Karnah; the ground above 7,000 feet being largely under snow, systematic fossil-collecting and the obtaining of more precise data regarding the stratigraphy and tectonics of the Pre-Palæozoics had to be postponed till next season.

As anticipated, the present season's work tends to establish the parallelism of the formations of N. E. Hazara with those of N. W. Pir Panjal. The fold-lines from these two areas, containing strata which are broadly similar, converge to and fuse in a prominent N.-S. syntactic belt with a strong depression of its axis to the south. The south-western foot of the Pir Panjal, along its entire length, is overthrust on the Murrees along two parallel thrust-planes, enclosing between them a strip of Eocene and Carbon-Trias rocks. This feature persists, in the main, through the Kafir Khan Range and the Kishenganga Valley, a total distance of 110 miles, and although the ground beyond this point to Balakot is not mapped in detail, the same double thrust-plane, along with the highly characteristic belt of strata which it delimits on either side (together with the sandwiched strip), is met with again at Balakot on the west side of the syntaxis, and forms the south-eastern boundary of the older Hazara formations against the Murree zone.

It is this double, narrow-looped thrust-plane which brings out in prominent relief the syntaxial belt of the north-western Himalaya. This zone of transverse strike in the Himalaya is about 360 miles in length and 40 miles broad, wherein all the fold-systems of the region are bundled and forced in one severely compressed zone of N.-S. strike, whereas on either side of it the strike rapidly turns towards the S. W. or S. E. There is a sharp southerly pitch of the syntaxis whereby progressively newer folds appear to the south, the youngest being the long tapering bay of Murrees terminating at Khagan, in the very centre of the sheaf.

Although no clear sections have been found, from such observations as Mr. Wadia has been able to make, the inclination of the Panjal thrust-plane appears to be generally not less than 25° and is at many places greater than 45°, though for relatively short distances both these limits may be exceeded. The dip of the strata as of the fault-planes is invariably inwards.

No mylonitic zone of crushed rocks was observed along the sole of the thrusts, though the amount of lateral movement of the Pre-

Cambrian slates over the Nummulitic series, especially at the west side of the Murree bay appeared to be considerable.

Attock District.

The area geologically surveyed by Sub-Assistant H. M. Lahiri during the season lay entirely in the Attock district and comprised the major portion of the northern half of Sheet 43 C/2 and the strip of country lying to the south and east of the Indus in the southern quarter of 43 C/1. The ground surveyed coincides with the western termination of the Kala Chitta range. The hills are divisible into two distinct groups, one consisting of limestones and confined to the north-eastern portion of the region and the other lying to the south-west of the limestone hills, composed of sandstones.

The geological formations mapped consisted of Trias, Giumal series, Nummulitic series, Murree series and Alluvium. The lithology of the various formations is similar to Sir Edwin Pascoe's descriptions of the rock-systems exposed in the Chak Dalla area (*Mem. Geol. Surv. Ind.*, Vol. XL, pt. 3, pp. 383-388). The Trias, which is the oldest formation mapped, covers a considerable area in the Kala Chitta limestone hills and is responsible for the belt of high hills that form the back-bone, as it were, of the range. A few recognizable fossils obtained from the usually unfossiliferous Triassic limestone include, among others, *Pecten* and *Terebratula*. The Giumal beds overlying the Trias are roughly divisible into an upper stage of limestone and marl and a lower one of sandstones and sandy shales. The lower Giumal shales are often highly carbonaceous and attain considerable thickness in the exposures bordering the Indus in Sheet 43 C/1. The lowest beds in the series contain *Belemnites* and *Gryphœa*, and, in some places, fragmentary ammonites of the *Perisphinctes* and *Macrocephalites* types. From the presence of the ammonite genus *Macrocephalites*, the age of the Basal Giumal beds appears equivalent to that of the Chari of Kachh and the Kellaways of Baluchistan. The Upper Giumal beds also yielded a number of fossils which, together with those from the basal beds and the Trias, have been sent to England for determination and description by specialists. The Lower Nummulitics overlying the Giumals consist of the usual fossiliferous bluish-grey limestones with an occasional pisolitic bed or greenish shale at the base. The fossils collected from this formation included *Assilina granulosa*, *Lucina* sp., *Conoclypeus* sp., *Isis* sp., etc. In the fresh-water Lower Chharat shales that overlie the Lower

Nummulitics is a characteristic bed consisting of a thin ferruginous gritty sandstone abounding in small fragmentary vertebrate bones. In the lower division of the Upper Chharat stage, Mr. Lahiri observed the characteristic marly rock containing abundant casts of lamellibranchs belonging to the genera *Cardita*, *Placuna* and *Corbula*. The topmost member of the Eocene in the area is the typical rock designated by Pinfold as "Nummulite Shale" which is composed entirely of the tests of *Nummulites* and *Assilina*. Amongst the fossils obtained from this horizon were *Nummulites atacicus*, *Assilina papillata* Nuttall, *Ostrœa* sp., *Gryphœa* sp., etc. The Eocene beds are overlain by Murree rocks that constitute the strike-hills occupying the country to the south-west of the limestone hills.

The central structure in the limestone hills is an anticline mostly overfolded north and north-eastwards on its northern limb, so that for the greater part of the northern and north-eastern flanks of the anticline, the sequence is inverted, the Lower Nummulitics being seen dipping under the Giumal beds and these latter under the Trias which forms the core of the anticline. The anticline is flanked on the north and north-east by a squeezed syncline occupied by Lower Nummulitic beds. Narrow, elongate, often disconnected outcrops of the underlying Giumals occur as inliers in the Lower Nummulitic rocks of this syncline. The dominant feature of the structure on the south flank of the central anticline is overfolding and overthrusting from the north. As a result of overthrusting, almost throughout the Eocene-Mesozoic boundary on this flank, the Lower Nummulitics are seen in juxtaposition with the Trias, the intervening Giumals having been completely pinched out. The dips of beds on the southern flank of the limestone hills are mostly northerly, the amount varying from 30° to 75°. As noted by Sir Edwin Pascoe further east, the Trias, Giumals and the Lower Nummulitics constituting the main Kala Chitta range are overthrust southwestwards on the Chharat and Murree beds along a fault-line that is traceable almost throughout the south-western foot and flank of the Kala Chitta limestone hills. The beds along this fault-line are, in some places, highly disturbed by repeated folding and thrusting within a narrow zone. Southwest of the fault, the country is occupied by Murree and Chharat beds, their dips near the fault being either vertical or steeply northeast. Further away from the fault-line, the Murree beds have a general south-westerly dip.

What Panipat has been to the history of the peoples of India, the Salt Range of the Punjab has been to her geologists. The dissected scarp from the Jhelum to the Indus and beyond might well be described as the geological battle-ground of India. There are few places in the world upon which the opinions of geologists have differed so fundamentally as they have upon the problem of the Salt Range. Some regard the salt marl as of Pre-Cambrian or Cambrian age, others would place it at the other end of the entire geological sequence and group it as Tertiary! Some have held that on this side of the Indus the salt is Cambrian while that on the right bank is Tertiary; others consider that whatever age is assigned to the salt it should be the same for both banks. Another view is that the salt marl is intrusive and perhaps of an igneous origin. Scarcely a year passes without some paper upon this classical area or upon one or another of its many problems appearing. One of the latest was published in these Records scarcely a year ago and in it were ably marshalled the arguments in favour of assigning to the saline series a true stratigraphical position beneath the Cambrian. One writer, quoted in this paper, has gone so far as to state that "the discovery....of Trilobites in the strata associated with the salt of the Persian Gulf area more or less establishes the early Cambrian or Pre-Cambrian age of the salt of North-west India." A still more recent paper (R. V. V. Anderson. *Bull. Geol. Soc. Amer.*, Vol. 38 1927), records (p. 672) the discovery in shale in the upper part of the Saline series in the Khewra Gorge of fragmentary remains of dicotyledonous leaves, placing the age of the deposits as not older than Lower Cretaceous; one of the specimens is described as almost certainly of Tertiary age. [1]

Salt Range, Punjab.

Definite evidence such as the above is of the greatest importance and carries unavoidable conviction, but it seems obvious that the complete elucidation of the Salt Range problem can only be accomplished by continuous careful geological mapping on the excellent 1-inch Survey of India map-sheets which were not available when Wynne carried out his pioneer survey. This important work has been entrusted to Mr. E. R. Gee who, during the months of March, April and the early part of May 1928, was deputed to the Salt Range for the double purpose of commencing a re-survey of the range, and of examining certain areas, at the request of the Commissioner, Northern India Salt Revenue Department, with a view to the future exploitation of rock-salt.

[1] Since this report went to Press a further contribution to the literature on this area has appeared in the Report of the British Association (Glasgow) 1928, by H. de Böckh, G. M. Lees, and F. D. S. Richardson. See also *Quart. Journ. Geol. Soc.*, lxxxiv, p. 591.

For the purpose of acquiring a general acquaintance with the geology of the different parts of the range, Mr. Gee made a preliminary examination of the following representative sections along the southern scarp of the Salt Range: (1) the gorge to the north of Baghanwala (32° 43′ : 73° 14′); (2) Kathi Kas, ¾ mile east of Jutana (32° 43′ : 73° 9′ 30″); (3) the area north and west of Chanuwala (32° 43′ 30″ : 73° 8′); (4) the area around Makrach (32° 40′ : 72° 53′ 30″); (5) the Nilawahan north-north-west of Kandwal (32° 32′ 45″ : 72° 39′ 30″); (6) the gorge north of Kattha Masral (32° 31′ 30″ : 72° 25′ 30″); (7) the river-sections north of Rukhla (32° 26′ 30″ : 71° 57′); (8) several sections around Sakesar (32° 32′ 30″ : 71° 56′); and (9) the Wahr River (Bakh Ravine) near Nammal (32° 40′ 30″ : 71° 48′ 30″).

In this eastern portion of the Salt Range the lower groups of strata are well represented. The succession is as follows:—

5. Salt Pseudomorph group.
4. Magnesian Sandstone group.
3. Cambrian Shale group.
2. Purple Sandstone group.
1. Salt Marl.

The Salt Marl is well-exposed in the area to the west of Jutana, and is usually characterised by an uppermost band of massive white gypsum. This gypsum bed is observed beneath the Purple Sandstone group of the Kathi Kas. The lower part of the Purple Sandstone group consists of purple-red, somewhat shaly clays with bands of fine sandstone, passing up into more massive sandstones with thin bands of clay. Massive purple-red and buff-coloured sandstones prevail in the upper part of the series which is here several hundred feet thick. The Cambrian Shale group which follows is very distinct from these lower beds in its lithology but appears to pass up gradually into the massive calcareous and dolomitic sandstones of the Magnesian Sandstone group. The purple clay bands of the upper horizons of the shale series appear, however, to remain fairly constant when traced to the west, and will probably be most useful in detailed mapping. Above the massive, thick, Magnesian Sandstone series, the purplish-red and light-green shales and flaggy sandstones of the Salt Pseudomorph group are very characteristic, forming a very distinct lithological group. These beds crop out over a wide area to the south and west of Ara

Rest House. In the vicinity of this latter locality, capping the Salt Pseudomorph group along the highest parts of the range, a boulder-bed, consisting of crystalline boulders in a greenish sandy or clayey matrix and only a few feet in thickness, is occasionally observed beneath the nummulitic limestone scree. It is followed by yellowish-green soft sandstones on which rest the olive-green gypsiferous shales including the Baghanwala coal-seam. These shales are capped, in this area, by only a thin representative of the Nummulitic Limestone group.

Large areas of the foot-hills to the north and west of Chanuwala appear to be formed of the red and purple-red salt-marl, including irregular masses of gypsum. This salt-marl, from surface evidence, appeared to Mr. Gee to be much-disturbed and not *in situ;* how far this is due purely to atmospheric agencies, or is related to the original tectonics of the locality, is not yet ascertained. In the stream-sections to the north and west the higher groups are well-exposed, the boulder-bed having thickened very considerably.

On the road from Khewra to Makrach, *viâ* Pid, the Salt Pseudomorph group is considerably thinner, whilst the overlying Boulder-Bed is well represented. The junction shows the basal bed of the latter series to include masses of the flaggy purple-red sandstones of the Salt Pseudomorph group. To the north of Makrach village the succession is as follows :—

9. Massive Nummulitic Limestones.
8. Thin, gypsiferous olive-green shales—the representative of the Chittidand coal-seam horizon.
7. Purple and red clays, passing down into massive purple-red and white sandstone.
6. Greenish soft sandstones and clays, often with strings of carbonaceous material, and including a basal bed with crystalline boulders.
5. Purple-red and light green flags and sandstones, 15 to 20 feet thick.
4. Magnesian Sandstone group, probably thinner than to the east.
3. Cambrian Shale group.
2. Purple Sandstone group.
1. Red Salt Marl, with an uppermost horizon of massive gypsum,

No. (5) evidently represents the remnant of the Salt Pseudomorph Shale group, and in a section examined about two miles west-north-west of Makrach, this group was observed to have died out completely, the boulder-bed resting immediately on the Magnesian Sandstone group. No. (7) represents the incoming of the Speckled Sandstone group ; the lower reddish-purple and light-coloured sandstones of this group appear to pass down gradually into the yellow-green sandstones which overlie the boulder-bed.

The succession in the Nilawahan locality is as follows :—

10. Massive Nummulitic Limestones.
9. Shales including a 2 to 4-foot coal-seam.
8. Marls and sandstones with nummulites in the upper part, and numerous *Terebratulæ* and Echinids in the lower portion.
7. Pisolitic hæmatite band, passing into a white pisolitic clay.
6. Calcareous sandstones and massive white and cream-coloured limestones with numerous brachiopods—*Productus*, *Spirifer*, etc.; soft shaly sandstone and carbonaceous shale bands in the lower part.
5. Thick purple and lavender clays with sandstones below, passing down into greenish sandstones with a basal bed, about 1 foot thick, of rounded crystalline boulders.
4. Magnesian Sandstone group, very thin, and possibly absent in some sections.
3. Cambrian Shale group.
2. Purple Sandstone group.
1. Red Salt Marl.

Group (5) evidently represents the Speckled Sandstone series, considerably thicker than at Makrach. Overlying the lavender clays of the upper part of this group, with no apparent break, are several bands of massive limestone and calcareous sandstone, which attain a thickness of over 80 feet in the Ratani Kas south of Bhal village, and include numerous fossils. The pisolitic hæmatite and white clay bed appears to represent a true laterite deposit, probably derived from a dark green very ferruginous sandstone with numerous small rounded pebbles of ferruginous matter, which occurs at the same horizon in other sections in this locality.

In the area to the north of Kattha Mr. Gee notes another marked change in the succession—the dying out of the Cambrian Shale

representative. In certain sections this horizon is still included as a band of purplish-grey shales and thin sandstones, with a basal pebble-bed similar to that observed to the east. This remnant of the Cambrian Shale group is, however, only about 30 feet in thickness. In other sections the boulder-bed rests immediately on the massive sandstones of the Purple Sandstone group, the matrix of the lower portion of the bed being, apparently, derived from purple sandstones similar to those on which it rests. From an examination of these sections alone, one would probably doubt the existence of a large stratigraphical break between the two groups. This boulder-bed is, in this area, very thin but equally constant in its occurrence. The Speckled Sandstone group is well represented, and the succeeding limestone series has thickened very considerably.

The succession in the area north of Rukhla (Warcha Mandi), is as follows:—

6. Thick Permian limestones, passing down into calcareous sandstones and grey limestones, among which are intercalated two bands of black carbonaceous shale.
5. Thick lavender clays passing down into massive purple-red and light-coloured sandstones.
4. Greenish sandstones and sandy shales with strings of carbonaceous material, and a thin basal bed including crystalline boulders.
3. Purple Sandstone group.
2. Red Salt Marl, with an uppermost gypsiferous zone.
1. An alternating succession of blue-green gypsiferous clay beds, thin grey vesicular dolomite, and dark brown shales, giving a decided smell of oil when heated.

The lowest group (1) crops out along the centre of the anticline about 1 mile north of the Salt Mine. Mr. Gee remarks that the exposures observed suggest that these beds underlie the Salt Marl. The latter, however, is much disturbed in the immediate neighbourhood of these outcrops, and a more detailed examination might lead to a modification of this view. The boulder-bed (4) rests immediately on the Purple Sandstone group, some of the boulders occurring in slight depressions of the surface of the uppermost Purple Sandstone bed. The passage up into the main portion of the Speckled Sandstone group (5) is gradual. No break is suggested

between this group and the Permian limestones which follow. Within the lower band of carbonaceous shale in the lower part of this group leaf impressions, including *Gangamopteris* and *Glossopteris*, were found, adding further evidence to the previously suggested Talchir age of the boulder-bed which occurs at the base of the Speckled Sandstone group. The discovery of these plant-fossils had been made, earlier in the season, by Dr. G. de P. Cotter. In the upper carbonaceous band the impressions of several bi-valves were found.

Up the slopes to Sakesar, the Ceratite-bearing limestones of Triassic age come in above the massive Permian beds. These are followed by a series of massive white, yellow and reddish sandstones with some blue-grey and light-coloured clays, for which a Jurassic age has been previously suggested. To the north of Sakesar these latter beds were found to include a number of well preserved plant impressions of Mesozoic age, and lignified fossil-wood. In the Dhodha Wahan near the path to Amb, the boulder-bed at the base of the Speckled Sandstone series is seen to rest on a very diminutive Purple Sandstone group, only about 100 feet thick, the latter group resting on the massive band of gypsum which forms the uppermost zone of the Salt Marl series. The Purple Sandstone group is, therefore, dying out rapidly to the west, and a short distance away, in the slopes near Ratta, it is absent altogether; thick dull-green and purplish shales with numerous crystalline boulders rest immediately against the massive gypsum zone of the Salt Marl.

In the south-western slopes of the range, about 4 miles south of Nammal, the Purple Sandstone group is again absent. Immediately succeeding the massive gypsum zone of the Salt Marl is a series of fine, splintery, dull-green and purplish shales including well-rounded crystalline boulders, and these beds pass up into thick sandstones and clays typical of the Speckled Sandstone group. The junction at the surface of the Salt Marl and the boulder-bed is rather disturbed, but considering the steepness of the slopes, and the ease with which these shale and clay beds disintegrate by weathering, this is to be expected. In the Bakh Ravine a fine section of strata, ranging from the massive Permian limestones up to the Tertiary sandstones and clays—previously allotted to the Lower Siwaliks—is exposed. The general succession was observed and a close examination made by Mr. Gee of the fossiliferous hori-

zons at the base of the Nummulitic Limestone series. At the base of these fossiliferous shales and limestones is a well marked bed of pisolitic hæmatite.

In most instances, the rivers of the areas visited had eroded their courses along the axes of anticlines, often faulted. A number of inclined faults and local slips, doubtless in some cases resulting from the solution of the seams of rock-salt beneath, have complicated the structure of the range. In the Nilawahan ravine the strata appeared to be definitely over-folded.

Himalaya, Simla Hills, Punjab.

During the spring of 1928 work was resumed by Mr. W. D. West in the Simla Hills, commencing on the western flanks of the Chor mountain. Sheet 53 F/5 has now been completed, except for a small area south-west of the Giri river, and a large part of sheet 53 F/9 has been mapped.

The work of previous years having shown that the Jutogh beds are disposed in several flat recumbent folds, the mapping of this series has been continued in detail, commencing near Rajgarh (30° 51′ : 77° 15′) on the west side of the Chor mountain, and continuing northwards round its northern and down its eastern sides, so that the rocks on all sides of the mountain adjacent to the Chor granite have now been mapped.

In the Memoir on this district which has been recently published[1], it is suggested that the Jutogh series of the Chor mountain forms an isolated outcrop, similar to that which caps the Simla ridge. The work done by Mr. West this season, however, has shown that, as a result of a gentle northerly dip which prevails throughout the district, and of a high ridge which runs out north from the Chor peak, the outcrop of the Jutogh series continues northward from the Chor mountain, very probably joining up with the outcrop of these rocks by Narkunda and Bagi on the Hindustan-Tibet road (31° 16′ : 77° 28′).

As regards the structure of the Jutogh series on the northern flanks of the Chor mountain, the repetition of the carbonaceous beds, which has been shown to occur on the southern flanks of the mountain, is maintained here also; the recumbent fold which this repetition is held to indicate has not yet been found to close. The next higher fold, which is found to the south of the mountain, is not seen on this side of it.

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[1] *Mem. Geol. Surv. Ind.*, Vol. LIII.

It is not to be expected that the overthrust which bounds these rocks below should be confined to one horizon, and it seems certain that a variable thickness of mica-schist commonly intervenes between the lowest carbonaceous band and the thrust. The exact position of the thrust is then not easy to determine, since these mica-schists are not superficially very different from some of the Chail beds below.

Throughout the area mapped this season the Jutogh beds are underlain by the Chail series. These differ little from the description given of them in previous General Reports, and the characteristic talc-schist band is usually a conspicuous feature.

Mr. West's detailed mapping has brought to light considerable faulting in the Rajgarh area (30° 51′ : 77° 15′), affecting more especially the Jutogh and Chail series. These normal faults tend to have a N.E.-S.W. trend, with a downthrow to the south-east. In the aggregate their throw must be quite 2,000 feet.

It was shown two years ago that the Jaunsar series and the Jaunsar overthrust, so well developed on either side of the Giri valley above Karganu, gradually become overlapped by the Chail series, until by Ranaghat on one side and Dhar on the other side of the valley they have been entirely cut out. This years mapping shows that further north-east the Jaunsar thrust reappears beneath the Chail thrust at Kufar (30° 59′ : 77° 25′), and the Jaunsar series soon attain their former dimensions.

The Blaini beds, traced to the north-east from Chala (30° 57′ : 77° 21′), were found by Mr. West to undergo a slow change. They gradually become schistose, so much so that had they not been traced continuously they would hardly have been recognised as Blaini. The dense limestone undergoes little change, but unfortunately dies out and is not seen beyond Ghar Dhar (30° 59′ : 77° 24′). The boulders in the boulder bed become crushed and flattened out, and the 'bleach slates' take on a prominent cleavage, often markedly oblique to the bedding.

On the north-east side of the Chor granite the Jutogh and Chail series are typically developed. Owing to the gentle dip the boundaries are very sinuous, the Jutogh-Chail boundary roughly following the course, Batewri, Chaupal, Khagna, Purwa, Kakra Dhar, Bhalu, Chiama and Kulag. It is of interest to note that the lowest horizon of the Chail series, characterised by a dark blue banded limestone, which is such a marked feature of the Chails to the west

of the Kalka-Simla railway, appears intermittently at the base of the Chails on the Chaupal spur and further south.

Mr. West remarks that on the Chaupal spur and in the Hamal *khad* the Chail series overlies unmistakable Jaunsar beds. Below these comes a considerable thickness of beds of doubtful correlation, which in their turn overlie the main outcrop of the Deoban limestone by Nerua (30° 55′ : 77° 38′). Further south, however, the Chail thrust, which marks the base of the Chail series, slowly approaches the Deoban limestone, until by Tikar (30° 49′ : 77° 35′), on the E. S. E. side of the Chor, the Chail series directly overlies the Deoban. In the intervening area, the Deoban beds are overlain by a fairly prominent but rather inconstant boulder bed; it closely resembles the Blaini boulder bed, but there is no limestone associated with it. The geology of this area has not yet been completely elucidated, and will have to be further examined.

The Deoban series, consisting mainly of massive limestone, but with some interbedded shales, is of great thickness. It has on the whole a very gentle north to north-westerly dip, and shows no signs of folding until near the Tons river. It forms the mountain Isu Tibba (30° 52′ : 77° 41′), and extends in a wide belt to the north-east. It is commonly full of chert, but no trace of any fossils has yet been found.

The whole of the eastern and north-eastern side of the Chor mountain appeared to Mr. West to be unaffected by any important normal faulting later than the overthrusting.

Mr. Auden was engaged from February to June in an examination of the country N. W. and S. E. of Solan, a station on the Kalka-Simla railway (1-inch sheets 53 E/4 and 53 F/1). The area includes a small part of the ground mapped by Mr. R. D. Oldham in 1888 and adjoins that of the recent map of Pilgrim and West.

The formations present in the area are: Jaunsar, Simla Slates, Blaini beds, Infra-Krol and Krol, and in the Tertiaries, Subathu, Dagshai, and Kasauli.

The Jaunsars were found in a narrow outcrop striking N.W.-S.E. near Malga, and faulted, probably by thrusting, against the Simla Slates. Mr. Auden maintains that part of the ground near Chhaosa marked on the map of Pilgrim and West as Jaunsars consists really of Simla Slates. He also puts forward the idea that the Jaunsars are tectonically (as well as perhaps stratigraphically)

above the Simla Slates and not below them as suggested by Pilgrim and West. Beds similar to a reduced facies of the Jaunsars are found in a subdivision of the Blaini group called the Gadhasar slates, which dip under the Blaini boulder bed. Mr. Auden suggests tentatively that these Gadhasar slates may be a reduced facies of the Jaunsars, whose correct position may be above the Simla Slates. The Jaunsars of Malga, and of the Jaunsar area by the Giri river, are thought to represent a thicker facies which has been brought over by the thrust, into proximity with the thinner Gadhasar facies. This view is advanced as worthy of consideration in the light of the exposures which Pilgrim and West themselves found where Jaunsars overlie Simla Slates (*Mem. Geol. Surv. Ind.* Vol. LIII, 1928, p. 87).

Mr. Auden gives evidence for the existence of another thrust—the Krol thrust—which has brought Simla Slates, Blaini, Infra-Krol sandstone and Krol rocks over Tertiaries and their floor of Simla Slates. This is indicated by the zig-zag disposition of the Tertiaries in between the narrow outcrop of Simla Slates east of Subathu and the extensive outcrop of Infra-Krols and other rocks. The main argument is based on the fact that everywhere the Tertiaries appear to underlie the rocks which are supposed to have been thrust over them. The alternative explanation, that of Medlicott and Oldham, that the Tertiaries are in synclines enclosed by Infra-Krol and other rocks is difficult to accept both for the structural reason given above, and because of the difficulty of correlating the rocks flanking one arm of the Tertiary wedge on the assumption that these flanking rocks are the limbs of an enclosing syncline. Some degree of correspondence should be expected between the two limbs, whereas actually the rocks of these imagined limbs are different. Mr. Auden states, however, that this argument is not entirely a safe criterion, since along much of the Blaini valley, every junction of rocks of different lithology is a fault or a shear zone. Hence beds may have been eliminated by faulting which might have established a similarity. On the interpretation put forward, the outcrops of Subathu beds near Solan represent windows under the Krol thrust, exposed by denudation of folds subsequent to the thrust movement. The same post-thrust folding is employed to explain the presence of the outlier of Jaunsars by Malga. Mr. Auden believes that decisive evidence will be obtained in the area to the north of Subathu.

The district is complicated by the imbrication of the Blaini beds. It is impossible to be certain what is the correct sequence in the Blaini series, since no two sections correspond. It is thought that to the N. W. of Solan there are two limestones and two boulder beds, while to the S. E. there may be only one limestone, with two boulder beds, one of which underlies the Gadhasar slates. The further correlation with the Jaunsar beds cannot as yet be fixed.

The evidence for the unconformity between the Krol series and the Krol sandstone is considered by Mr. Auden to be inconclusive, since the variations in thickness of the Krol sandstone are due largely to its splitting up in a S. E. direction and interbedding with the Infra-Krols. Nowhere has any angular unconformity been seen.

On the basis of metamorphism Mr. Auden holds that such differences as exist between the various formations may be largely explained by the reaction of their different lithologies to stresses, probably localised. Thus true slaty cleavage occurs not only in the Jaunsars, but in the Infra-Krols, and in one instance in the Lower Krol limestone. Fracture cleavage is described as very common, especially in the carbonaceous Infra-Krols and the Lower Krol limestone. These features are thought to have developed wherever suitable lithology has been associated with sufficient stress.

Mr. Auden hes found well rounded grains of quartz as small as 0·18 mm. in the Krol sandstone. Such rounding must be due to wind action, and the overlying Red Shales in the Krol series suggest that the conditions were arid. The proximity of Krol sandstone to the glacial beds of the Blaini requires explanation. It is of interest that two of Captain Palmer's specimens from the Shali area, probably from the Madhan sandstone, on slicing show excellently rounded grains. The rounding of grains may prove of value in correlation.

Rajputana.

In the field-season 1927-28 the Rajputana Party, consisting of Dr. A. M. Heron, Officiating Superintendent (in charge) and Mr. B. C. Gupta, Sub-Assistant, worked in the Mewar (Udaipur) State. During the first month Dr. Heron marched southward from Chitorgarh to the southern edge of the plain of central Mewar, where the country slopes steeply to the Som river, and then made a traverse west-

ward across this tract of mixed gneisses, inspecting Mr. B. C. Gupta's work of the previous season, which is described in the General Report for 1927.[1]

Dr. Heron then mapped the country north and south of Udaipur City, on the Central India and Rajputana standard sheets (1 inch to 1 mile) nos. 144, 145 and 146, and towards the end of the season inspected Mr. B. C. Gupta's work on standard sheets nos. 146, 147, 148, 174 and 175. The area covered by these two officers is about 50 miles along the strike and from 15 to 30 miles wide, and extends from about 10 miles north of Udaipur City to the southern frontier of Mewar, where it meets Dungarpur State along the Som river.

The oldest rocks are the banded gneisses of the plain of central Mewar, referred to above. Besides the great expanse upon the plain, they are exposed in an oval inlier in the extreme south of the State, extending across the Som river into Dungarpur, about 29 miles in length and 11 in breadth; in this inlier the composition of the complex is essentially the same as it is upon the plain, as described in the General Report for 1927.[2] The important differences are that basic rocks, epidiorites and hornblende-schists, are less common—though they do occur—and garnet is more abundant, in the inlier than in the main expanse. A coarse black biotite-schist, which often carries garnet and staurolite, is very prevalent in places; this may conceivably be a form of primitive sediment, highly metamorphosed. There is also banded biotite-gneiss, rather an indefinite and variable rock, and a coarse porphyritic granite, in veins parallel with the foliation, forms with the biotite-schist and biotite-gneiss a boldly banded composite gneiss. In the north of the inlier a fine grained and poorly foliated granite forms flatly domed outcrops, and everywhere in the complex there is much pegmatite and aplite, which clearly show the effects of pressure in granulating and rounding the larger crystals and inducing foliation in the finer interstitial material. The inlier is surrounded by the basement beds of the Aravallis, which rest upon it with an erosion unconformity, and form an isoclinal anticline.

A similar but smaller area is that north-west of Udaipur City, occupied by a rock with distinct resemblances to the Bundelkhand gneiss. In eastern Mewar[3] the Aravallis rest upon the eroded

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[1] *Rec. Geol. Surv. Ind.*, LXI, pp. 128-9.
[2] *Loc. cit.*
[3] *Loc. cit.*, p. 128.

surface of the Bundelkhand gneiss. Along the northern side of this smaller inlier the Aravallis appear to rest upon the gneiss (here a more or less foliated granite) with an erosion unconformity, but the evidence for this is not particularly clear. On the south side, however, according to Dr. Heron, the granite is undoubtedly intrusive in the Aravalli limestones, but it is not certain whether the intrusive granite is the same as the foliated gneiss in the north. They resemble each other, but further investigation is necessary to settle this and to explain the apparently contradictory evidence as to their relationship with the Aravallis.

The basement of the Aravallis is best seen around the periphery of the oval inlier of gneisses in the extreme south of the State, in an almost continuous chain of ridges, composed mainly of quartzite and arkose grit, with some impure limestones in lenticles below the grit, which latter passes upwards into the quartzites, and these into the phyllites which predominate so markedly over other types of sediment in the Aravallis. The erosion unconformity with which the grits lie upon the gneisses is convincing and the upward transition from grit, through quartzites into phyllites, is gradual and unbroken.

The structure is that of an isoclinal anticline, the axial plane of which dips to the south-west; within the gneissic area are several small detached outliers of limestone and quartzite, greatly sheared, and elongated in the direction of the strike. These may conceivably represent the tips of minor synclines in the roof of the anticline, or anticlinorium. At the north-western end of the oval, the grits, which are thin on the flanks of the anticline, expand into a great triangular mass, and become much more conglomeratic. Intervening between these and the gneisses is a local, but very thick, succession of greenish hornblendic schists and phyllites, often strongly garnetiferous, which, there is little doubt, represent bedded tuffs and a thick, coarse volcanic agglomerate. No flows were seen.

Above the basement beds the Aravallis consist in the main of a monotonously uniform succession of dark grey phyllites in which no structure can be made out, since traces of stratification have been completely removed and the dip of the foliation is vertical or to the west and south-west at high angles. In the south of the State they become fine biotite-schists, and small garnets are sometimes produced where metamorphism has been more severe. Over con-

siderable areas knots and lenticular beds of brown siliceous and ferruginous limestone are abundant in the phyllites, resembling the clay-ironstone nodules of the Carboniferous. As well as these scattered occurrences there are also great thicknesses of impure limestones, black or grey, and less commonly white, in colour, and highly siliceous, both with disseminated quartz, and with grey and brown quartz in lenticular and ramifying sheets and veins. These were probably originally of the nature of chert or other aqueous replacement of the limestone by silica, rather than the usual igneous vein quartz. The limestones appear to be in beds of a foot or two in thickness, but stratification is always obscure, and is usually obliterated by the secondary silicification, and by shearing and shattering.

Dr. Heron finds that a common accompaniment of the limestone is a coarse breccia, produced by the removal of the soluble contents of the limestone, calcium and magnesium carbonates, causing collapse of the insoluble quartz remainder by the weight of superincumbent strata or by the compressive stress of folding. The porous mass thus formed provides an easy avenue for circulating water carrying silica and iron in solution, and is ultimately cemented by ferruginous chert. Being very resistant to denudation, these breccia masses give rise to steep, conical hills, typical examples of which diversify the low, rolling expanse of phyllites in the *Girwa*, the valley surrounding Udaipur City.

In spite of the general and very pronounced mechanical disturbance which the limestones have undergone, there is little sign of mineral metamorphism, and such minerals as talc, tremolite and sericite occur only where acid intrusives are very abundant, and where the association of phyllites, limestones and granite is passing into composite gneiss.

A few thin quartzites, and rare occurrences of pebble-bands with a phyllitic matrix were met with, but, as always, the Aravallis are predominantly an argillaceous formation.

Dr. Heron notes that the phyllites are very commonly veined with white quartz and there are two extensive tracts, one a strip from one mile to two miles wide, extending from 6 miles south-east of Udaipur City for a distance of 30 miles, and the other, much wider, commencing south of Salumbar (24° 12′ : 74° 5′) and running south-eastwards into Dungarpur State, in which interfoliar injection of the phyllites, or rather mica-schists, by aplite and pegmatite,

has formed a banded composite gneiss. Along the strike, and across the strike, normal uninjected phyllites grade into mica-schists so much intruded with acid igneous material that the latter predominates in the resulting gneiss.

Besides the myriads of veins of pegmatite and aplite constituting the composite gneiss, granite occurs in the Aravallis in six major bosses and a number of small intrusions, isolated or in groups. The granite is of two types. That which forms two bosses south-east and east of Udaipur City, with many satellite intrusions, is fine-grained and indistinctly crystallized, and almost devoid of ferro-magnesians. Being easily weathered, it never projects above the surface of the soil. It may be the same as that mentioned above, which invades the Aravalli limestones on the edge of the inlier of gneiss north-west of Udaipur City. The other forms a small boss north-west of Salumbar, and three much larger ones to the south-east of Salumbar, with veins scattered through the area of composite gneiss within which the bosses lie. This is a rather coarse granite, porphyritic and unfoliated, with abundant biotite, and forms tors and flat domes rising from the plain.

Basic intrusives, epidiorites and hornblende-schists, are met with in the Aravallis, and in the extreme south-west of the area surveyed, near Kalianpur (24° 0′ : 73° 58′) is a group of irregular masses of steatitic and dolomitic rocks, probably allied to the "magnesian phase" described by Mr. Middlemiss in Idar,[1] to which he ascribes an intrusive origin, as ultrabasic igneous rocks highly metamorphosed.

The Raialo marble is found in three long and narrow strips, the tips of isoclinal synclines infolded in the Aravalli phyllites and composite gneiss. The rock is a saccharoidal white or pink dolomite, in thick beds, and sparsely jointed, and forms steep and rugged verdureless ridges. The basement conglomerate is sporadically developed, and consists of a layer, never more than a few feet thick, of small rounded quartz pebbles in a calcareous matrix.

In his work in North-Eastern Rajputana[2] Dr. Heron classified the Raialo limestone and quartzite as the lowest division of the Delhi system. The last few seasons' work in Mewar, where outcrops of the Raialos are much more extensive than in the limited sections along the Alwar-Jaipur frontier, leads him to believe that the unconformity between the Alwar series and the Raialo series

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[1] *Mem. Geol. Surv. Ind.*, XLIV, pp. 97, 103.
[2] *Mem. Geol. Surv. Ind.*, XLV, pp. 23-8, 50-1.

is far more important than he thought, and that the Raialos should be removed from the Delhi system, and given a place intermediate between the Delhi and Aravalli systems.

Delhi rocks, consisting of arkose conglomerates and reddish quartzites, extend as high ridges along the north-eastern edge of the area surveyed, forming the most striking physical features of the country. They are disposed in three isoclinal synclines, with axial planes dipping to the north-east in the northern one, and to the south-west in the other two. The synclines overlap *en echelon* for 10 miles or more, and each syncline narrows in the south, in the section in which it is overlapped, from its normal width of 2 to 3 miles, to a mere shred. On the west of the area also, a number of smaller parallel synclines of conglomerate, with a more complicated arrangement, were found by Dr. Heron to extend south as far as latitude 24° 24′, and they also show narrowing to the south.

These conglomerates represent the basal beds of the Delhi system, where it rests with a profound unconformity upon the Aravallis and the older gneisses. The upper formations of the main Delhi syncline to the west are not represented in these outliers. The pebbles consist chiefly of quartz and quartzite, of very varying sizes, in a felspathic and micaceous matrix; the pebbles are usually compressed and sheared, and the matrix foliated, obliterating the bedding.

Bijaigarh Shales, Son Valley, United Provinces.

The revision of the 32-inch Geological Map of India rendered desirable a re-examination of the base of the upper Vindhyan system of the Son valley. In our present scheme the black Bijaigarh Shales with the Lower Kaimur Sandstone are included in the upper Vindhyan. Dr. C. S. Fox was deputed to re-examine the section in the Son valley area around Bijaigarh in the Mirzapur district, and found no evidence of unconformity from the base of the Lower Kaimur sandstone through the overlying Bijaigarh Shales to the Upper Kaimur sandstone. Below the Lower Kaimur sandstone is a black shale of Semri type, at times almost a black cherty hornstone. In a few sections a curious breccia was found to intervene between this black shale and the Lower Kaimur sandstone. This breccia has been recognised by Dr. Heron as very similar in structure and appearance to the Tirohan breccia which separates the upper and lower Vindhyans along the northern margin of the sweep of the Vindhyan outcrops.

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MISCELLANEOUS NOTE.

New Chromite Localities.

A specimen from Hotag Hill, Silli Estate (23° 21′ : 85° 50′ 30″), Ranchi District, brought by Mr. K. B. Dutt, of Calcutta, to this office for examination and report, has been identified as chromite. In thin section (No. 18131) the chromite is seen to be associated with serpentinous minerals. This appears to be the first recorded occurrence of chromite in the Ranchi district.

A specimen from Baida Chauk, about 5 miles from Mandar Hill Station (24° 48′ 30″ : 87° 1′ 30″) in the Bhagalpur district of Bihar and Orissa, which was forwarded to this department for identification by Mr. T. Chowdhury, prospector, of Jamtara, East Indian Railway, was found to contain chromite.

A. L. COULSON.

O

MGIPC—M—VIII-4-21—3-5-29—850.

ERRATA.

Page 32, lines 1 and 6, *for* "Shahyindaung" *read* "Shabindaung."
Page 104, lines 14 and 24, *for* "Tabyin Clays" *read* "Yaw Stage."
Page 104, line 19, *for* "Tabyins" *read* "Yaws."

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1929. [August.

SIVARAU SETHU RAMA RAU: BORN 15TH OCTOBER 1874: DIED 27TH MARCH 1929.

IT is with much regret that I have to record the death of Rao Bahadur Sivarau Sethu Rama Rau, Assistant Superintendent in the Geological Survey of India, who died on the 27th of March at the age of 54 years. After passing the B. A. examination of the Madras University, he entered Government service as a Mica Inspector in the Nellore District of the Madras Presidency on the 1st of March 1899. On the 11th of February 1904, he joined the Geological Survey of India as a Sub-Assistant. In recognition of his useful survey work in Burma and elsewhere, he was promoted on the 6th of September 1919 to the grade of Assistant Superintendent. During his 25 years' service he worked in Central India, the Central Provinces, the Raniganj and Jharia Coalfields and in Burma, but it was in the latter province that most of his service was spent. Out of the 14 years spent in Burma, 6 were passed in the Tavoy and Mergui districts of Tenasserim and the rest in the dry zone chiefly in connection with the oil fields. In the survey of Mergui, his work took him to the inaccessible and jungly regions along the Siamese border. In these almost uninhabited areas where villages are rare and insignificant in size, Sethu Rama carried on geological work under conditions of personal discomfort and not a little danger from the bands of dacoits which infest the border region. During the great European War, he participated in our geological investigation of the Burmese wolfram deposits required for munition

purposes. It was in recognition of his valuable services in this connection that the Government of India were pleased to promote him to the grade of Assistant Superintendent and subsequently to confer on him the title of Rao Bahadur in 1920. He was an indefatigable worker and took no long leave during his service. A paper on the Stratigraphy of the Singu-Yenangyat area by him was published in Records, Vol. LIII, and a memoir on the Geology of the Mergui District is now in preparation for the Press. Sethu Rama Rau's unassuming manners and amiable disposition attached him to all with whom he came in contact. Living very simply himself, he spent his money and time freely in helping others, and more than one struggling student or unfortunate menial has benefited by his charity and kindly sympathy. He was due to retire from the service on the 15th of October of this year, and his premature death is deplored by all his colleagues in the service.

E. H. PASCOE.

ON THE SPECIFIC GRAVITY AND PROXIMATE COMPOSITION OF SOME INDIAN VITRAINS BY L. LEIGH FERMOR, O.B.E., D.SC., A.R.S.M., M.I.M.M., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 1 to 4.)

CONTENTS.

I. INTRODUCTION.

IN a paper in the previous volume of these Records, I gave an account, based upon a study of carefully picked specimens, of the relationship between the specific gravity and ash contents of certain coals from the Kurasia (Korea) and Bokaro coalfields.[1]

The macroscopically homogeneous substances making up the majority of the Bokaro and Kurasia coals are three in number, namely, the fundamental colloidal substance or bright coal (vitrain), the greasy-lustred dull coal (durain), and a fine-grained micaceous carbonaceous shale ("m. c. shale"). In addition, "mother of coal" (fusain) is sometimes seen as films parallel to the bedding. In the paper to which a reference has been made above, a tabular statement is given of a considerable number of proximate analyses and

[1] *Rec. Geol. Surv. Ind.*, LX, pp. 313-357 (1928). *See also* "Coals as Colloid Systems," *Nature*, May 5, 1928, p. 705.

specific gravity values of carefully picked specimens of the coals and carbonaceous shales of Bokaro, and a curve is plotted to show the ash contents and specific gravity of each specimen analysed. The density-ash curve is linear up to about 40 per cent. of ash and then concave towards the density ordinate.

On the basis of their macroscopic physical appearance, the specimens analysed can be arranged into two series as follows :—

——	Ash contents.	Specific gravity.	Deviation.[1]
	Per cent.		
I. Vitrain-durain series (bright, silky and dull coals).	2·31 to 39·11	1·28—1·65	0
II. Vitrain-carbonaceous shale series (shaly coals, coaly and carbonaceous shales).	27·61 to 89·41	1·49—2·58	− 5 to + 45

On studying the density-ash curve it is seen that the coals of the vitrain-durain series conform to the following linear law :—

$$a=100(g-k)$$

in which a stands for the percentage of ash, g for the specific gravity of the coal as determined, and k for the specific gravity of ash-free coal in the particular coalfield. To the practical man the above equation means that every one per cent. of ash in coal raises the specific gravity by 0·01[2] and consequently, given k, the ash contents of a specimen of coal can be deduced by multiplying by 100 the difference between the specific gravity of the specimen and k. The values adopted for k are 1·26 for Bokaro, and 1·28 for Kurasia.

From the fact that a density-ash value for coal of the vitrain-durain series follows this linear rule, it is deduced that these coals must be suspensoid colloid systems in which vitrain acts as the dispersion medium and the ash contents as the disperse phase (suspensoid), with the vegetable detritus contained in the durain present as a second disperse phase (coarse suspension).

[1] The deviation of a coal is the difference measured in units of 0·01 between the specific gravity as actually determined and the specific gravity required by the linear rule.

[2] Since the paper under reference was published, I have discovered that others had already noticed that the specific gravity of "pure coal" could be approximately deduced from that of an actual piece of coal by subtracting 0·01 for each one per cent. of ash. *See* 'Practical Coal Mining', Vol. I, C. A. Seyler, p. 80 (1907); and W. Pollard, "Coals of South Wales", Memoirs of the Geological Survey of England and Wales, Second Edition, p. 12 (1915).

The coals and shales of the second series (vitrain-carbonaceous shale series) do not, in their density-ash relationships, follow the linear rule. Instead, the density-ash curve is that for mechanical mixtures of vitrain and shale, which may accordingly, in the nomenclature of colloids, be regarded as coarse suspensions, in so far as the carbonaceous and mineral matter are admixed, and not merely interlaminated with one another.

Having discovered that a linear rule applies to the coals of the first series, it is, of course, easy to deduce from the curve the specific gravity (k) of ash-free coals (*i.e.* ash-free vitrain) of this series. It is found to be 1·26 for coals from Bokaro and 1·28 from coals from Kurasia. Having discovered that the specific gravity of ash-free vitrain for these two fields is not the same, the question arose whether a separate value of k had to be adopted for each field, and this led to the analysis and the determination of the specific gravities of specimens of vitrains from various coalfields. Some of the determinations had been completed by the time the foregoing paper went to press, and sufficient data had been obtained to show that the specific gravity of vitrain is higher, the higher the moisture contents (*loc. cit.*, p. 349). From this fact it was deduced that vitrain itself is a colloid system (emulsoid or gel), in which the moisture-free vitrain and the moisture may be regarded as separate phases. As the preliminary data concerning vitrain from various localities yielded results of interest, the opportunity was taken of the fact that several officers of the Geological Survey of India were engaged on the resurvey of certain Indian coalfields under the supervision of Dr. Fox, to ask these officers to collect specimens of vitrain for this investigation. I am indebted accordingly to the following officers for a supply of suitable specimens:—Dr. Fox (Jharia and Jainti coalfields, and Punjab Siwaliks), Mr. Hobson (Rajmahal Hills), Dr. Dunn (Hutar coalfield), Mr. Gee (Raniganj coalfield), and Mr. Auden (Raniganj coalfield). In addition, I have to thank Mr. C. S. Middlemiss (Kashmir jet), Mr. Lancaster (Giridih), and Mr. J. Thomas (Sohagpur) for specimens from the coalfields named. There are still many Indian coalfields from which specimens of vitrain have not been collected and analysed, but enough data have now been obtained to show the general range of variation of specific gravity and proximate composition of Indian vitrains, and accordingly this paper is offered for publication. Its objects are twofold—(*a*) to show the range of the variation in the proximate

composition of vitrains as compared with the range of variation in the specific gravity thereof, (*b*) to deduce average figures for the value of *k* for the ash-free vitrains from various coalfields in order to enable mining men to make practical use of the linear rule given above in deducing the ash contents of coals from specific gravity determinations.

All the analyses and specific gravity determinations given in this paper were made by Mahadeo Ram, Laboratory Attendant, Geological Survey of India, except where otherwise indicated.

II. METHODS.

The material selected for analysis was chosen by me and picked either by myself or by Mahadeo Ram, in the latter case the picked material was examined by me before being used.[1] The specific gravity determinations of coals and shales given in the previous paper were made on specimens large enough for investigation on a Walker's balance. Vitrain, however, occurs usually interbanded with durain or carbonaceous shale, although bands of vitrain two or three inches thick are occasionally found, the bands of vitrain, from which it has been necessary to select material, are usually from ¼ to 1 inch thick, so that it is but rarely that pieces of vitrain large enough for investigation on the Walker's balance can be obtained. Vitrain is a colloid that cracks usually into polygonal fragments with curved or conchoidal fracture surfaces, and consequently the material used has been in the form of small polygonal fragments, and the specific gravity thereof has been determined by means of the specific gravity bottle, with which it is more difficult to secure accurate results than when working in large pieces on the Walker's balance. The selected material, after the specific gravity determination, has been left for at least a day to become air-dried at air temperatures before being powdered for analysis. It must be emphasised here that in all cases the whole of the material upon which the specific gravity has been determined has been powdered for analysis. Duplicate picked material has, however, been kept in glass tubes for purposes of reference.

It is not unlikely that the moisture contents of vitrain vary with the temperature, pressure and humidity of the air, but no

[1] I have also included a few analyses of material selected by Dr. Fox which was not seen by me. The specimens to which this remark applies represent Barakars, Raniganj and Assam and are marked "Fx" without any other number.

attempt has been made to record the meteorological conditions under which each specimen has been studied, nor would such work have been of value in the absence of knowledge concerning the manner in which differences of meteorological conditions affect the moisture contents of vitrain, so that it would not be possible to adjust the moisture contents as determined to a uniform standard of temperature, pressure and humidity. The fact, nevertheless, that the results when plotted show some sort of systematic scheme of variation indicates that the meteorological conditions are not as important in their effect upon the results as might at first sight have been anticipated. Nevertheless, an investigation of the effects of temperature, pressure and humidity upon the moisture contents of one specimen of vitrain would be of considerable value and would provide valuable data supplementary to those presented in the present paper, and would perhaps lead to the selection of a standard method of carrying out in the future determinations of the moisture in vitrain and other coals.

It is unnecessary to discuss here the methods of proximate analyses of coal adopted for this investigation. As is well known, the determination of the four items, moisture, volatile matter (by which is meant combustible volatile matter), fixed carbon and ash, depend upon the heating of the coal for standard times with flames of standard strength. The most difficult part of such an analysis is the exact determination of the volatile matter and fixed carbon. A hotter flame than the standard will cause the analyst to return a higher figure for the volatile matter and a lower figure for the fixed carbon than under standard conditions and *vice versa.* In Table 1 (page 196) I have shown in one column the year of each analysis. On comparing these dates with the corresponding figures for the volatile matter and fixed carbon it will be seen that the general tendency is for the analyses made in 1907, 1913, 1917, and 1919, to show substantially lower volatile matter and higher fixed carbon than the adjacent analyses made in 1928. This fact caused me to ask Dr. Christie, Chemist to the Geological Survey of India, whether any change had taken place in the methods of coal assay in our laboratory between 1919 and 1928. After investigation Dr. Christie informed me that the only change he could detect was that the platinum crucible used by Mahadeo Ram for the determination of volatiles was lost in 1925. This crucible (No. 5) weighed about 30 grammes and had a capacity of 36 c.c. The

crucible (No. 111) now in use weighs about 31 grammes and has a capacity of 32 c.c. Some of the intermediate determinations were made in crucibles (Nos. 30-31) weighing about 50 grammes and holding 32 c.c. Dr. Christie remarks that it is not possible to say if crucible No. 5 had a particularly tight-fitting lid. Another fact that may cause particular assays to yield higher figures for volatile matter and lower figures for fixed carbon under standard conditions is variation in the gas pressure in the mains of the Calcutta Gas Supply; and a smaller gas pressure in the past would explain the lower volatiles returned in the earlier analyses. On account of the general difference between the volatiles and fixed carbon in the earlier and the later analyses, the data for these two constituents in the earlier analyses have not been used in drawing the curves in which the results are summarised on Plates 1 and 2. A study of the data in Table 1 will show, however, that although there is this general difference between the volatile matter and fixed carbon in the earlier and later analyses, the period of analysis has not affected the moisture, so that for this constituent use has been made, in plotting the curves, of both the earlier and later analyses.

III. TABLES OF SPECIFIC GRAVITY AND PROXIMATE ANALYSIS.

The data obtained are given in Tables 1 to 6. Table 1 gives the data for the vitrains of the Barakar stage, 12 coalfields being represented by 25 analyses. Table 2 gives the data for vitrains of the Raniganj stage, 2 coalfields (Raniganj and Jharia) being represented by 6 analyses. Table 3 collects 10 analyses representing 4 coalfields in Assam, of which Cherrapunji and Lairangao are of Eocene (Nummulitic) age and Makum and Nazira of Oligocene or Miocene age. Table 4 gives 5 analyses of so-called jet from the Lower Siwaliks of Kashmir. Table 5 shows 3 analyses of vitrain from the Siwaliks of the Punjab. Table 6, with 2 analyses of Tertiary (Lower Eocene) coal from the Island of Skye in Scotland, is added, for, although the analyses belong to the older period of investigation and consequently show unduly low volatile matter and unduly high fixed carbon, yet the figures of moisture contents can be used.

In these tables the proximate analysis and specific gravity (g) as returned by the analyst are given in columns 6-10. These are followed in columns 11-14 by data reduced to an ash-free basis. The specific gravity (g) on an ash-free basis is obtained by deducting

0·01 for each 1 per cent. of ash present from the specific gravity (g) as actually determined, as follows from the linear equation already given (page 190). Thus :—

$$g_1 = g - \frac{a}{100}$$

The value of k, the specific gravity constant for pure vitrain, for any field, is obtained by averaging the values of g_1 for the various specimens. Thus in Table 1 the values of g_1 for Barakar coals from the Raniganj field are shown in column 11 :—1·254, 1·255, 1·260, 1·262 and 1·268. The mean of these is 1·260, which may be taken as the value of k for the Raniganj field. Table 7 shows the average composition and average specific gravity (k) on an ash-free basis for the vitrain in each of the fields for which data are given in Tables 1 to 6 arranged in order of the value of k.

The data tabulated in Tables 1-7 have been plotted on 4 plates, on each of which the specific gravities are plotted as ordinates and the moisture, volatile matter, and fixed carbon as abscissæ. There are consequently three curves on each plate showing the relationship of specific gravity respectively to moisture, volatile matter, and fixed carbon. As these 3 constituents total to 100, the three curves on any one diagram add, of course, to a vertical straight line. In addition curves have been added to each plate showing the relationship between specific gravity and fuel-ratio.

On glancing over Tables 1-6 it will be seen that the Barakar vitrains (Table 1) differ from those represented in other tables by containing, in the range of lower specific gravities, lower volatiles and higher fixed carbons than the remaining coals. The Barakar vitrains are consequently plotted separately in Plate 1. The vitrains of the Raniganj series have also been plotted separately (Plate 2). The remaining (of Tertiary age) with their higher volatiles and lower fixed carbons (in the low specific gravity range) have all been plotted in Plate 3 in three sets of curves, the coals represented being in order of age, Eocene (Assam), Eocene (Skye), Miocene (Assam), Siwalik (Kashmir and Punjab). In Plate 4 the average data of Table 7 for all the volatile vitrains have been plotted together in order to see whether they tell a consistent story. In each plate the division between caking and non-caking coals is shown in order to ascertain if possible the effect that vitrains in the composition of vitrain have upon its caking properties.

TABLE 1.—*Analyses and specific gravities of picked specimens of*

Coalfield.	Locality or seam.	Field No.	Register No.	Date of analysis.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash.	Specific gravity. G.
Raniganj[1] .	Damagaria seam, Damagurria Colliery.	Rb. 14	..	1928	0·61	30·51	65·62	3·26	1·287
Raniganj . .	Ditto .	Rb. 14	..	1928	1·45	31·49	63·94	3·12	1·286
Giridih . .	Lower Karharbari Seam.	Gd. 1	..	1928	0·84	36·01	61·60	1·55	1·274
Bokaro . .	Seam 13, Joint Colliery.	F. 377	23·996	1919	1·99	27·47	68·23	2·31	1·283
Raniganj . .	Ramnagar Seam, Ramnagar.	Rb. 2	..	1928	1·56	32·00	62·19	4·25	1·302
Bokaro[2] . .	Seam 13, Joint Colliery.	F. 377	23·996	1917	1·21	27·76	68·53	2·50	1·277
Jharia . .	Seam 14, Bhowra quarry.	Jh. 10	..	1928	1·58	35·60	60·82	2·00	1·282
Raniganj . .	Begunia Seam, Begunia.	Rb. 1	..	1928	1·75	35·69	59·34	3·22	1·294
Bokaro . .	Seam 13, Sawang .	F. 114	26·926	1919	2·24	29·83	64·32	3·61	1·300
Jharia . .	Seam 14, Phularitand	Fx.	..	1928	0·85	27·89	70·90	0·36	1·272
Raniganj . .	Laikdih Seam, Ramnagar Colliery.	Rb. 3	..	1928	1·31	31·90	65·32	1·47	1·283
Jharia . .	Seam 17, Baliari Colliery.	..	..	1928	1·67	31·24	63·12	3·97	1·308
Jainti . .	Bottom of lowest seam.	Ja. 1	..	1928	2·42	33·76	61·64	2·18	1·295
Jharia . .	Seam 17, W. Bhagaband.	Jh. 11	..	1928	1·7	32·54	62·11	3·58	1·311
Pench Valley, Barkui area.	Barkui Colliery .	..	..	1907	2·20	26·38	69·56	1·86	1·295
Jharia . .	Seam 17, Bhatlagarhi	Jh. 13	..	1928	2·26	32·96	62·80	1·98	1·300
Jharia . .	Seam 9A, Keshalpur	Fx.	..	1928	1·04	26·10	72·08	0·78	1·291
Jharia . .	Seam 17, Bhatlagarhi	Jh. 13	..	1928	1·99	33·76	60·16	4·09	1·330
S. Karanpura .	Argada . . .	Kp. 3	..	1928	6·27	33·95	58·20	1·58	1·305
Kurasia . .	Dauk huri . .	D. 183	26·669	1913	9·80	29·18	60·51	0·51	1·30
Sohagpur . .	Burhar . . .	So. 1	..	1928	9·66	44·30	42·06	3·38	1·334
Kurasia . .	Daukihuri . .	D. 183	26·669	1919	13·02	29·56	57·10	0·32	1·306
Talcher . .	Handidhua, Shaft II	Tch. 1	..	1928	15·08	38·59	45·76	0·57	1·329
Hutar . .	Harilong . .	Ht. 1	..	1928	13·93	41·75	43·57	0·75	1·343
Pachwarha .	Amrapara . .	Rj 2	..	1928	16·26	40·36	41·27	2·11	1·366
Pachwarha .	Mahashpur . .	Rj. 1	..	1928	14·17	39·59	45·10	1·14	1·370

NOTE.—All analyses and specific gravity determinations by

vitrain of Barakar age from 12 coalfields.

Data on ash-free basis.				Fuel-ratio. $\frac{C}{V}$	Colour of ash.	Caking properties.	Collector.
G_1	M_1	V_1	C_1				
1·254	0·63	31·53	67·84	2·15	White . . .	Cakes strongly .	E. R. Gee.
1·255	1·50	32·50	66·00	2·03	Yellowish white .	Ditto .	Ditto.
1·258	0·85	36·58	62·57	1·71	Ochreous buff .	Ditto .	Lancaster.
1·260	2·04	28·12	69·84	2·48	Yellow . . .	Ditto .	L. L. Fermor.
1·260	1·63	33·42	64·95	1·94	Light brown . .	Ditto .	E. R. Gee.
1·252	1·24	28·47	70·29	2·47	White . . .	Ditto .	L. L. Fermor.
1·262	1·61	36·33	62·06	1·71	Light cream . .	Ditto .	C. S. Fox.
1·262	1·81	36·88	61·31	1·66	Brown . . .	Ditto	E. R. Gee.
1·264	2·32	30·95	66·73	2·16	White . . .	Ditto .	L. L. Fermor.
1·268	0·85	27·99	71·16	2·54	Olive . . .	Ditto .	C. S. Fox.
1 268	1·33	32·38	66·29	2·05	Cream . . .	Ditto .	E. R. Gee.
1·268	1·74	32·53	65·73	2·02	Brown . . .	Ditto .	C. S. Fox.
1·273	2·47	34·51	63·02	1·82	Light brown . .	Ditto .	Ditto.
1·275	1·83	33·75	64·42	1·91	Cream . . .	Ditto .	Ditto
1·276	2·24	26·88	70·88	2·64	Brown . . .	Cakes, but not strongly.	Shaw, Wallace & Co.
1·280	2·30	33·63	64·07	1·91	Vinaceous pink .	Cakes strongly .	C. S. Fox.
1·283	1·05	26·30	72·65	2·76	Wood brown . .	Ditto .	Ditto.
1·289	2·07	35·20	62·73	1·78	Burnt umber . .	Ditto	Ditto.
1·289	6·37	34·50	59·13	1·71	Cream . .	Ditto .	L. L. Fermor.
1·295	9·85	29·33	60·82	2·07	Buff . . .	Sinters slightly	Ditto.
1·300	10·00	45·85	44·15	0·96	Cream buff .	Cakes strongly .	J. Thomas.
1·303	13·06	29·66	57·28	1·93	Brown . . .	Does not cake	L. L. Fermor.
1·323	15·17	38 81	46·02	1·18	Dark brown . .	Cakes very poorly .	Ditto.
1·335	14·03	42·07	43·90	1·04	Olive . . .	Ditto .	J. A. Dunn.
1·345	16·61	41·24	42·15	1·02	Buff . . .	Does not cake .	G. V. Hobson.
1·359	14·33	40·05	45·62	1·14	Brown . . .	Sinters slightly .	Ditto.

Mahadeo Ram, except (1) by P. C. Roy and (2) by B. C. Gupta.

TABLE 2.—*Analyses and specific gravities of picked specimens of*

Coalfield.	Locality or Seam.	Field No.	Registered No.	Date of analysis.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash.	Specific gravity. G.
Raniganj . .	Dishergarh Seam, Lachipur.	Rr. 2	..	1928	2·21	42·17	51·16	4·46	1·299
Jharia . .	Barunga Seam .	Fx.	..	1928	2·29	36·49	87·62	3·60	1·292
Jharia . .	Lohpiti Seam .	Fx.	..	1928	2·26	36·42	56·57	4·75	1·312
Raniganj . .	Ghusick Seam, Kalapahari.	Rr. 1	..	1928	5·26	38·83	52·64	3·27	1·300
Raniganj . .	Poniati Seam, Ningah	Rr. 3	..	1928	3·38	38·28	54·56	3·78	1·307
Raniganj . .	Ghusick Seam, Kalapahari.	Rr. 1	..	1928	6·24	38·18	53·80	1·78	1·289
Raniganj . .	Samla Seam, Baidyanathpur.	Rr. 4	..	1928	9·61	38·20	51·79	0·40	1·295
Jharia . .	Hustodih (vitrainised bark of tree) roof of seam.	Fx.	..	1928	3·03	34·80	60·96	1·21	1·307
Raniganj . .	Samla Seam . .	Rr. 4	..	1928	12·88	34·54	52·08	0·50	1·314

TABLE 3.—*Analyses and specific gravities of picked specimens of*

Coalfield.	Locality.	Field No.	Registered No.	Date of analysis.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash.	Specific gravity. G.
Lairangao .	Lairangao . .	Cp. 1	..	1928	2·14	50·38	42·71	4·77	1·262
Makum . .	Namdang . .	Fx	..	1927	2·04	42·27	54·48	1·21	1·240
Lairangao .	Lairangao . .	Sh. 8	..	1928	1·02	45·58	49·44	3·96	1·285
Makum . .	Ledo Colliery .	..	L. 942	1928	2·36	44·45	51·90	1·29	1·264
Cherrapunji .	Cherrapunji . .	Sh. 6	..	1928	0·91	46·03	52·76	0·30	1·272
Cherrapunji .	Ditto	Sh. 6	..	1929	0·96	44·09	54·67	0·28	1·275
Nazira . .	Borjan A . .	Fx.	..	1927	4·35	48·00	45·70	1·95	1·304
Nazira . .	Tel Pung, Outcrop B	..	6·655	1928	4·30	43·60	51·79	0·31	1·323
Nazira . .	Tel Pung . .	..	6·655	1928	4·82	40·59	50·28	0·30	1·323
Nazira . .	Wakching . .	Fx.	..	1927	8·15	38·48	52·98	0·39	1·328

vitrain of Raniganj age from 2 coalfields.

Data on ash-free basis.				Fuel-ratio. $\frac{(C)}{V}$	Colour of ash.	Caking properties.	Collector.
G_1	M_1	V_1	C_1	$\left(\frac{Fc_1}{Vm_1}\right)$			
1·255	2·31	44·14	53·55	1·21	Dark brown . .	Cakes strongly .	E. R. Gee.
1·256	2·38	37·85	59·77	1·57	White . .	Ditto .	C. S. Fox.
1·264	2·37	38·24	59·39	1·55	Cream buff . .	Ditto .	Ditto.
1·267	5·44	40·14	54·42	1·35	Pinkish buff . .	Ditto .	E. R. Gee.
1·269	3·51	39·79	56·70	1·42	Mars brown . .	Ditto .	Ditto.
1·271	6·35	38·87	54·78	1·41	Pinkish buff . .	Ditto .	Ditto.
1·291	9·65	38·35	52·00	1·36	Raw sienna . .	Ditto .	J. B. Auden.
1·295	3·07	35·22	61·71	1·75	Ochreous buff .	Ditto .	C. S. Fox.
1·309	12·95	34·71	52·34	1·50	Cinnamon . .	Does not cake .	J. B. Auden.

vitrain of Eocene and Miocene age from 4 coalfields.

Data on ash-free basis.				Fuel-ratio. $\frac{C_1}{V_1}$	Colour of ash.	Caking properties.	Collector.
G_1	M_1	V_1	C_1				
1·214	2·25	52·90	44·85	0·85	Light brown .	Cakes strongly .	L. L. Fermor.
1·228	2·06	42·79	55·15	1·28	Brown . . .	Ditto .	C. S. Fox.
1·245	1·06	47·46	51·48	1·08	Cream . . .	Ditto .	L. L. Fermor.
1·251	2·39	45·03	52·58	1·17	Light brown .	Ditto .	?
1·269	0·91	46·17	52·92	1·15	Light cream . .	Ditto .	L. L. Fermor.
1·272	0·96	44·21	54·83	1·24	Cream . . .	Ditto .	Ditto.
1·284	4·44	48·95	46·61	0·95	Buff . .	Cakes fairly strongly	C. S. Fox.
1·320	4·31	43·74	51·95	1·18	Brown . . .	Cakes strongly .	? F. R. Mallet.
1·320	4·83	44·73	50·44	1·13	Dark brown . .	Ditto .	Ditto.
1·324	8·18	38·68	53·19	1·40	Yellowish brown .	Cakes, but not strongly.	C. S. Fox.

TABLE 4.—*Analyses and specific gravities of vitrains of Siwalik age*

Locality.	Field No	Register No.	Date of analysis.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash.	Specific gravity. G.
Budhan	Ksh. 2	..	1928	9·28	53·20	31·30	6·22	1·337
Budhan (Jet)	Ksh. 2	..	1928	10·97	46·54	37·14	5·35	1·378
Bunikarali (Jet).	Ksh. 4	..	1928	14·04	41·47	42·32	2·17	1·380
Baratla (Jet)	Ksh. 3	..	1928	15·31	43·55	37·94	3·20	1·407
Budhan	Ksh. 2	..	1928	14·24	36·46	43·29	6·01	1·474

TABLE 5.—*Analyses and specific gravities of vitrains of Siwalik age*

Locality.	Field No.	Register No.	Date of analysis.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash.	Specific gravity. G.
Bhakra gorge, Kangra district . .	Sw. 1	..	1928	7·41	40·38	48·92	3·29	1·360
Ditto . .	Sw. 1	..	1928	7·84	36·56	51·86	3·74	1·399
Amli, Kangra district	Sw. 2	..	1928	11·74	45·50	40·50	2·26	1·404

TABLE 6.—*Analyses and specific gravities of vitrains of Eocene age*

Register No.	Date of analysis.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash.	Specific gravity. G.
28·827	1915	11·41	30·85	53·53	4·21	1·345
28·826	1915	11·72	31·25	52·98	4·05	1·359

from Kashmir.

Data on ash-free basis.				Fuel ratio, $\frac{C}{V}$	Colour of ash.	Caking properties.	Collector.
G_1	M_1	V_1	C_1				
1·275	9·89	56·73	33·38	0·59	Liver brown . .	Does not cake.	C. S. Middlemiss.
1·325	11·59	49·17	39·24	0·79	Indian purple. .	Ditto .	Ditto.
1·358	14·35	42·39	43·26	1·02	Seal brown . .	Ditto .	Ditto.
1·375	15·81	44·99	39·20	0·87	Indian purple. .	Ditto .	Ditto.
1·414	15·15	38·79	46·06	1·19	Ditto .	Ditto .	Ditto.

from Punjab.

Data on ash-free basis.				Fuel-ratio, $\frac{C}{V}$	Colour of ash.	Caking properties.	Collector.
G_1	M_1	V_1	C_1				
1·327	7·66	41·75	50·59	1·21	Indian purple. .	Cakes, but not strongly.	C. S. Fox.
1·362	8·14	37·98	53·88	1·42	Ditto	Ditto .	Ditto.
1·381	12·01	46·55	41·44	0·89	Light brown. . .	Does not cake .	Ditto.

from Skye, Scotland.

Data on ash-free basis.				Fuel-ratio, $\frac{C}{V}$	Colour of ash.	Caking properties.	Collector.
G_1	M_1	V_1	F_1				
1·303	11·91	32·21	55·88	1·73	Light brown . .	Does not cake .	L. L. Fermor.
1·318	12·21	32·57	55·22	1·69	Brown	Ditto .	Ditto.

TABLE 7.—*Average analyses and specific gravities on an ash-free basis of vitrains from 21 sources.*

Coalfield.	Age.	Number of analyses. Averaged.	Specific gravity. K.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Fuel-ratio. C/V	Date of analysis.	Caking properties.
Lairangao .	Eocene .	2	1·230	1·65	50·18	48·17	0·96	1928	Cakes strongly.
Makum . .	Miocene	2	1·236	1·56	45·13	53·31	1·22	Do.	Ditto.
Giridih . .	Barakar .	1	1·258	0·85	36·58	62·57	1·71	Do.	Ditto
Bokaro[1] .	Barakar .	3	1·259	1·87	29·18	68·95	2·37	1917, 1919	Ditto.
Raniganj .	Barakar .	5	1·260	1·38	33·34	65·28	1·97	1928	Ditto.
Cherrapunji .	Eocene .	2	1·271	0·94	45·19	53·87	1·19	Do.	Ditto.
Jharia . .	Raniganj .	3	1·272	2·61	37·10	60·29	1·62	Do.	Ditto.
Jainti . .	Barakar .	1	1·273	2·47	34·51	63·02	1·82	Do.	Ditto.
Jharia . .	Barakar .	7	1·275	1·63	32·25	16·12	2·09	Do.	Ditto.
Barkui[1] .	Barakar .	1	1·276	2·24	26·88	70·88	2·64	1907	Cakes, but not strongly.
Raniganj .	Raniganj .	6	1·277	6·70	39·33	53·97	1·37	1928	Cakes strongly.
S. Karanpura	Barakar .	1	1·289	6·37	34·50	59·13	1·71	Do.	Ditto.
Kurasia[1] .	Barakar .	2	1·299	11·45	20·50	59·05	2·00	1913, 1919	Does not cake—or sinters slightly.
Sohagpur .	Barakar .	1	1·300	10·00	45·85	44·15	0·96	1928	Cakes strongly.
Skye[1] . .	Eocene .	2	1·310	12·06	32·39	55·55	1·71	1915	Does not cake.
Nazira . .	Miocene .	4	1·312	5·44	44·01	50·55	1·16	1928	Cakes—usually strongly.
Talcher .	Barakar .	1	1·323	15·17	38·81	46·02	1·18	Do.	Cakes very poorly.
Hutar . .	Barakar .	1	1·335	14·03	42·07	43·90	1·04	Do.	Ditto.
Rajmahal .	Barakar .	2	1·352	15·47	40·65	43·88	1·08	Do.	Does not cake—or sinters slightly.
Punjab . .	Siwalik .	3	1·357	9·27	42·09	48·64	1·17	Do.	Does not cake.
Kashmir .	Siwalik .	3	1·382	15·10	42·06	42·84	1·06	Do.	Ditto.

[1] The volatile matter, fixed carbon and fuel-ratio of these early analyses are given unadjusted. After adjustment by transference of 5 per cent. from fixed carbon to volatile matter the fuel-ratios for these 4 vitrains become 1·58, 2·07, 1·57, and 1·35, respectively.

IV.—DISCUSSION OF DATA.

1. The Vitrains of the Barakar Stage.

The analyses and specific gravities of vitrains from coals of the Barakar stage are assembled in Table 1, and the data, on an ash-free basis, are plotted in Plate 1. As already explained, certain of these analyses—Bokaro, Barkui and Kurasia—were done in earlier years (1907, 1913, 1917, and 1919) with a different crucible, which, with other factors, appears to have caused the determinations of volatile matter to be higher, and consequently of fixed carbon lower, than in the case of coals assayed in 1928. The amount of this difference appears to be from 5 per cent. to higher figures in the case of the high-moisture Kurasia coals. These earlier analyses have also been plotted, the relative points being distinguished by circles, but in constructing the curves weight has been given to the moisture figures only. It will be seen that the points for volatile matter and fixed carbon marked by circles are distant from the curves in each case. Assuming an average difference of 5 per cent. between the older and newer determinations of volatile matter and fixed carbon, the spots representing these earlier analyses have been moved a distance representing 5 per cent. (+ for the volatile matter and - for the fixed carbon) as indicated by the small arrows in the diagram. The new positions have been marked by triangles. In every case, this transference brings the spots marked by triangles nearer to the curve adopted than in the original position marked by circles.

A study of the figures in Table 1 and of the curves in Plate 1 shows that with increasing specific gravity the general trend is for the moisture and volatile matter to increase and for the fixed carbon to decrease. The changes are not, however, regular. The moisture contents are practically constant—namely 0·63 to 2·47 per cent., with an average of about 1·5 per cent.—for the range of specific gravities 1·257 to 1·283. There is then a rapid increase of moisture with specific gravity from, say, 4·5 per cent. moisture to 11 per cent. moisture over the range of specific gravity 1·289 to 1·300. The moisture then increases again very slowly from 11 per cent. to 15·8 per cent. whilst the specific gravity is increasing from 1·300 to 1·359.

The curve of combustible volatile matter is roughly parallel to that of moisture, but the total increase of volatile matter between the specific gravities of 1·257 and 1·359 is only from 32·75 to 40·75

per cent. (a total of 8 per cent.), against an increase in the moisture contents of 15 per cent. for the same range of specific gravity.

The fixed carbon behaves, of course, in complementary fashion to the moisture *plus* volatile matter and decreases from 66 per cent. to 44 per cent., whilst the specific gravity is increasing from 1·257 to 1·359. The fixed carbon also, like the moisture and the volatile matter, shows a range of low specific gravity and a range of high specific gravity in which the percentage changes but little, joined by a short section in which the percentage changes rapidly with the specific gravity, the change being in the case of the fixed carbon a fall.

The ratio of fixed carbon to volatile matter, usually known as the fuel-ratio,[1] is plotted as a separate curve at the right-hand end of the diagram. The fuel-ratios given in Table 1 have been used with the exception of those for the earlier analyses. These earlier data have been adjusted by reducing the fixed carbon by 5 per cent. and increasing the volatile matter by the same amount in each case as follows :—

Coalfields.	Date of analysis.	Specific gravity.	Fuel-ratio before adjustment.	Fuel-ratio after adjustment.
Bokaro	1919	1·260	2·40	1·96
Bokaro	1917	1·252	2·47	1·95
Bokaro	1919	1·264	2·16	1·72
Barkui	1907	1·276	2·64	2·07
Kurasia	1913	1·295	2·07	1·62
Kurasia	1919	1·303	1·93	1·51

From the curve as drawn it appears that the fuel-ratio decreases gradually with increasing specific gravity, except perhaps at the top of the range.

Omitting the Kurasia figures the data can, however, be placed into two distinct groups as shown in Table 8 :—(1) a group of low specific gravity (average value 1·268) and low moisture contents (average value 1·89 per cent.), but high fuel-ratio (average value

[1] P. Frazer. 'Classification of coals;' Second Geological Survey of Pennsylvania, Second Report, pp. M.M. 142, 143 (1879).

1·07), and (2) a group of high specific gravity (1·332), high moisture contents (14·03 per cent.), but low fuel-ratio (1·07).

TABLE 8.—*Summary of data relative to the specific gravity, moisture contents and fuel-ratio of vitrain from the Barakar stage.*

—	Coalfields.	Specific gravity		Moisture.		Fuel-Ratio.		Caking properties.
		Range.	Average.	Range.	Average.	Range.	Average.	
				Per cent.		Per cent		
Group of high fuel-ratios.	Raniganj, Jharia, Bokaro, South Karanpura, Giridih, Barkui.	1·254-1·289	1·268	0·63-6·37	1·89	1·66-2·76	1·97	Strongly caking.
Anomalous group.	Kurasia .	1·295-1·303	1·299	9·85–13·06	11·45	1·51-1·62	1·56	Do not cake —or sinter slightly.
Group of low fuel-ratios.	Sohagpur, Talcher, Hutar, Pachwarha.	1·300-1·359	1·332	10·00-16·61	14·03	0·96-1·18	1·07	Non-caking (or cake but feebly).

Between these two groups lie two analyses of vitrain from Kura ia. Before adjustment the fuel-ratios of these two vitrains were 2·07 and 1·93, which clearly brought them into the high fuel-ratio group in spite of their high moisture contents and non-caking quality. After adjustment, however, in the manner described above, these fuel-ratios fall to 1·62 and 1·51, respectively, which are still only just below the lower limit of the first group. A study of the analytical data in Table 1 will show, however, that by comparison with adjoining analyses a greater transference than 5 per cent. would have been justified. Even so large a transference as 10 per cent. would, however, bring the mean fuel-ratio down only to 1·24, so that it seems necessary to accept that the Kurasia vitrains occupy an intermediate position between the two groups. This position is consistent with the intermediate specific gravity, but on grounds of moisture-contents and non-caking qualities, the Kurasia vitrains must be regarded as more closely allied to the vitrains of low fuel-ratio.

It is interesting to note the distribution of the coalfields from which these two groups of vitrains have been collected. The low-moisture group with high fuel-ratio is composed entirely of vitrains from the Damodar Valley group of fields (Raniganj, Jharia, Bokaro, South Karanpura, Jainti), with the exception of Giridih and one outlying field, namely Barkui, in the Central Provinces. The vi-

trains of the Damodar Valley fields all come from undoubted Barakars, the Giridih vitrain is from the Karharbari stage, which is regarded by some as the lowest section of the Barakars. These data support, therefore, the view that the Barkui coalfield in the Pench Valley is also on true Barakars.

None of the high-moisture vitrains of low fuel-value come from the Damodar Valley fields, the home of the original Barakars, with the exception of the Hutar specimen. The others come from outlying fields, namely, Sohagpur in Central India, Talcher in Orissa, and Pachwarha in the Rajmahal Hills. These are all areas in which the attribution of the strata to the Barakars is based on general grounds supported by somewhat meagre palæo-botanical evidence. Can these data be interpreted as indicating that the strata containing these high-moisture vitrains are not truly Barakars, but belong to some newer horizons ? Or have we to search for a reason why the vitrains of some parts of the Barakars show low moisture and high fuel-ratios, whilst vitrains from other portions of the Barakars show high moisture and low fuel-ratios ? In view of the intermediate position held by the Kurasia vitrains, the latter seems perhaps the more probable of these two alternatives, but the possibility must not be overlooked that a study of these supposed Barakar vitrains suggests that some of these strata may be incorrectly correlated.

2. Vitrains of the Raniganj Stage.

The Raniganj stage has not been certainly recognized outside the Damodar Valley line of coal-fields, and specimens of vitrains have been obtained from only two of these fields, namely, Raniganj and Jharia. Consequently, we have many fewer analyses to discuss than with the Barakar series. The data, based on 9 analyses, are assembled in Table 2. When plotted the Raniganj data suggest a linear increase of moisture and decrease of volatile matter and fixed carbon with increasing specific gravity, as shown in Plate 2. The three sets of spots marked " Fx " represent three specimens analysed for Dr. Fox, the material of which I did not see, and which fall rather wide of the curves. As they represent the Jharia field, and the remaining 6 analyses represent the Raniganj field, the difference between th vitrains from these two fields may be actual. The curves have been drawn, however, with reference

to the data from the Raniganj field only. The fuel-ratios are shown in the same diagram and the Jharia specimens show rather different fuel-ratios from the Raniganj specimens. For comparison with the data given in Table 8, the Raniganj data may be summarised as follows:—

TABLE 9.—*Summary of data relative to the specific gravity, moisture-contents and fuel-ratio of vitrain from the Barakar Stage.*

—	SPECIFIC GRAVITY.		MOISTURE.		FUEL-RATIO.	
	Range.	Average.	Range.	Average.	Range.	Average.
Raniganj field .	1·255-1·309	1·277	2·31-12·95	6·70	1·21-1·50	1·37
Jharia field .	1·256-1·295	1·272	2·37-3·07	2·57	1·55-1·75	1·62
Both fields .	..	1·275	..	5·34	..	1·46

The vitrains of the Raniganj stage appear to occupy a position intermediate as regards specific gravity, moisture and fuel-ratio between the two groups of the Barakar vitrains, namely, those with a high fuel-ratio and those with a low one. The data for the anomalous Barakar vitrains of Kurasia are not dissimilar from those of Raniganj. In particular the following comparison is intriguing:—

Coalfield.	Analysis.	Specific gravity.	Moisture.	Fuel-ratio.
Raniganj . . .	Specimen Rr. 4	1·309	12·95	1·50
Kurasia . . .	Second analysis	1·303	13·06	1·51 (adjusted).

The vitrains of the Raniganj stage, Jharia coalfield, appear to be intermediate between those of the high fuel-ratio group of the Barakar vitrains and the vitrains of the Raniganj stage, Raniganj coalfield, as is shown by the following figures:—

—	Specific gravity.	Moisture.	Fuel-ratio.
Raniganj stage, Raniganj	1·277	6·70	1·37
Raniganj stage, Jharia	1·272	2·57	1·62
Barakar stage, high fuel-ratio . .	1·268	1·89	1·97

From this one may hazard the suggestion that the specimens from Jharia may come from a lower section of the Raniganj stage than those of the Raniganj coalfield.

Three of the vitrains from the Raniganj stage of the Raniganj field were collected from three different seams in order to ascertain whether there is any systematic change in properties and composition with depth, the order of the seams being as follows from above downwards :—

Ghusick,
Dishergarh,
Poniati.

In addition, a specimen was obtained from the Samla seam, the approximate position of which is supposed to be near the Dishergarh seam, but it occurs in another part of the coalfield, namely, the north-eastern portion. The data relative to these 4 seams are discussed in section 5, together with the data relevant to 4 seams of the underlying Barakars of the same field.

3. The Vitrains of Assam (Eocene and Miocene).

Analyses of specimens of vitrains from four different Assam coalfields are shown in Table 3. Of these the Lairangao and Cherrapunji coalfields are of Eocene (Nummulitic) age and lie on the Khasia plateau to the south of Shillong, whilst the Makum and Nazira coalfields are of Miocene age and lie in Upper Assam on the southern edge of the Brahmaputra Valley. The Eocene fields are almost undisturbed whilst the Miocene are steeply dipping. The data are plotted in Plate 3, separate curves for moisture, volatile matter and fixed carbon being plotted for the Eocene and Miocene vitrains, as also for the Siwalik vitrains discussed in the next section. One fuel-ratio curve, however, serves for all the three series of vitrains. It is a straight line from specific gravity 1·214 to specific gravity 1·327, the fuel-ratio increasing slowly from about 1·08 to 1·27. At the top of the diagram the fuel ratio decreases to below 1·0 (0·87 and 0·89) for the heaviest Siwalik vitrains (specific gravity=1·275 and 1·281, respectively). The whole of the Assam vitrains, both Eocene and Miocene, are strongly caking, except the heaviest Nazira (Watching) specimen with 8·18 per cent. of moisture, which cakes but not strongly.

4. The Siwalik Vitrains.

The data for the Siwalik vitrains are assembled in Tables 4 and 5. All the vitrains hitherto considered have been derived from definite coal seams in definite coal measures. The Siwalik vitrains do not so occur. Those for which data are given in Table 4 were collected by Mr. Middlemiss from stringers in lower Siwalik sandstones in Jammu in Kashmir, and the first specimen analysed in the laboratory of the Geological Survey of India was designated *jet* by the then Curator—Mr. H. Walker. The Punjab vitrains were collected by Dr. C. S. Fox and represent again trivial occurrences. "Sw. 1" was obtained from a gallery in Siwalik sandstones on the right bank of the Bhakra gorge of the Sutlej river, and "Sw. 2" from the Beas above Amli. The characteristics of these Siwalik vitrains are the high moisture and specific gravity and the low fuel-ratio. The data are plotted in Plate 3 with the Eocene and Miocene data. The variation in the volatile matter and fixed carbon of the three series of vitrains there plotted appear to follow no particular rule, but the average moisture and specific gravity increase with the youth of the occurrence. The fuel-ratio remains fairly steady in all three series.

In plotting the Siwalik data, no use has been made of the three analyses of specimen "Ksh. 2." The analysis showing the highest specific gravity was that first done. As this showed what was thought to be an abnormally low amount of volatile matter for vitrain of the high moisture and specific gravity shown, the analysis was repeated with the results shown against specific gravity 1·325. As the change of specific gravity was so large, the analysis was again repeated on the material still left, with the result shown against specific gravity 1·325. It was evident before the third analyses had been made that the material was undergoing decomposition. It is instructive to place below in chronological order the data on an ash-free basis:—

Date of analysis.	Specific gravity.	Moisture.	Volatile matter.	Fixed carbon.	Fuel-ratio.
21-6-28 . .	1·414	15·15	38·79	46·06	1·19
19-9-28 . .	1·325	11·59	49·17	39·24	0·79
24-9-28 . .	1·275	9·89	56·73	33·38	0·59

During the short period of three months, therefore, this vitrain decreased in specific gravity from 1·414 to 1·275, in moisture from 15·15 to 9·89, in fixed carbon from 46·06 to 33·38 and in fuel value from 1·19 to 0·59, whilst the volatile matter increased from 38·79 to 56·73. These changes took place in the moist Calcutta monsoon climate, although the material was kept in a corked tube except when the experiments were being made.

One of the Punjab Siwalik specimens was analysed twice. The two analyses show the following data, on an ash-free basis :—

Date of analysis.	Specific gravity.	Moisture.	Volatile matter.	Fixed carbon.	Fuel-value.
25-5-28 . .	1·327	7·66	41·75	50·59	1·21
22-9-28 . .	1·362	8·14	37·98	53·88	1·42

As the material was small in amount (contained orginally in a match box), it was not possible to make a third test, so that it is uncertain whether a continuous change was taking place in this case. If so, the direction of change was the reverse of that in " Ksh. 2."

5. The Vitrains of Skye (Eocene).

The vitrains of Skye, strictly speaking, should not be considered here. However, the two analyses already published (*Records, Geological Survey of India*, Vol. LX, p. 359) are available and are given in Table 6, as they help to reinforce the general story of increasing moisture with increasing specific gravity. The fuel-ratios given are too high and if the volatile matter and fixed carbon be adjusted as with other analyses by transferring 5 per cent. from the fixed carbon and the volatile matter, then the fuel-ratios fall to 1·37 and 1·33, respectively, which is not so much greater than the figure of about 1·25 for the corresponding specific gravity on the fuel-ratio curve, for the Tertiary Indian coals shown in Plate 3. The Skye coal is, of course, Lower Eocene in age.

6. The Lustre of Vitrain.

The material for the analysis of the Barakar and Raniganj, *i.e.*, Gondwana, vitrains has, in every case, been selected from the bright bands of banded coals. The material so selected is not, however, equally bright from locality to locality ; in fact, the Barakar vitrains range in lustre from exceedingly brilliant through bright to almost

dull, the lustre of the dullest varieties being perhaps comparable with that of pitch. This gradation in lustre in these structureless conchoidal-fractured material is so perfect that if the most brilliant is to be called vitrain, so must the dullest.

The material selected to represent the vitrain of Assam (Eocene and Miocene) is taken from coal almost the whole of which is of one substance, so that almost the whole of the coal can be regarded as vitrain. These Assam vitrains show conchoidal fracture and can be compared in lustre with vitrain in the middle portion of the range of lustre of the Barakar series. The Kashmir jet is identical in lustre with some of the Barakar vitrains, and must also be regarded as vitrain, as also must the Siwalik specimens from the Punjab. Small pieces of freshly fractured vitrain from various localities and horizons have been compared as regards lustre and arranged in order. The results are given in Table 10 with the corresponding moisture contents shown against each specimen.

TABLE 10.—*Indian Vitrains arranged in order of brilliance of lustre.*

Lustre.	BARAKAR.		RANIGANJ.		EOCENE AND MIOCENE.		SIWALIK.	
	Number of specimen.	Moisture.	Number of specimen.	Moisture.	Number of specimen.	Moisture.	Number of specimen.	Moisture.
Most brilliant	Gd. 1	0·85	..	..	..	..	..	..
	23·996	2·04	..	..	..	..	..	..
	Ja. 1	2·47	..	..	..	..	Ksh. 4	14·35
	Rb 2	1·13	..	..	..	..	..	..
	Jh. 10	1·61	..	..	..	..	..	..
Medium brilliant	23·926	2·32	..	..	..	..	..	..
	Rb. 3	1·33	..	..	..	..	..	..
	Jh. 11	1·83	Hunto-dih.	3·07	..	..	..	..
	Jh. 13	2·30	Rr. 1	6·35	..	..	..	..
Less brilliant	..	..	Rr. 2	2·31	Sh. 6	0·96	..	..
	Kp. 3	6·37	Rr. 3	3·51	..	..	..	..
	..	..	..	..	..	..	Ksh. 3	15·81
Bright	..	..	..	..	G. 655	4·83	..	..
	So. 1	10·00	..	..	..	..	..	..
Not brilliant, but becoming increasingly dull, the dullest resembling pitch in lustre.	..	..	..	..	Sh. 8	1·06	..	..
	26·669	13·06	..	..	Cp. 1	2·25	..	..
	Ht. 1	14·03	Rr. 4	12·95	..	..	Sw. 2	12·01
	Tch. 1	15·17	..	..	..	..	..	..
	Rj. 2	16·61	..	..	..	..	..	..
	Rj. 1	14·17	..	..	..	..	Sw. 1	8·14

It will be seen that in the Barakar series the vitrain becomes increasingly dull with increasing moisture. In other series also, a relatively dull lustre usually means high moisture, but one specimen of Kashmir jet with 14·35 per cent. of moisture is as lustrous as the most brilliant Barakar vitrains. On the other hand, Eocene coals from Assam though low in moisture are comparable in lustre with some of the less dull of the high-moisture Barakar vitrains.

V. THE CHANGE OF COMPOSITION OF VITRAIN WITH STRATIGRAPHICAL HORIZON.

In Table 7 average data arranged in order of specific gravity are assembled for the vitrains of each coalfield. From a study of these tables it will be seen that there is no general change with age. Tertiary vitrains provide the heaviest and the lightest on the list, and Barakar vitrains are found through a long range of specific gravity, from nearly the lightest to nearly the heaviest on the list. If we place the average data in order of stratigraphical age, we get the following :—

Stratigraphical position.	Number of analyses averaged.	Specific gravity k.	Moisture.	Volatile matter.	Fixed carbon.	Fuel ratio.	Caking properties.
Siwalik . . .	6	1·370	12·18	42·08	45·74	1·09	Non-caking.
Miocene . . .	4	1·312	5·44	44·01	50·55	1·16	Caking.
Eocene . . .	4	1·250	1·30	47·68	51·02	1·07	Caking.
Eocene (Skye) . .	2*	1·310	12·06	37·39	50·55	1·35	Non-caking.
Raniganj (Raniganj) .	6	1·277	6·70	39·33	53·97	1·37	Caking.
Raniganj (Jharia) . .	3	1·272	2·61	37.10	60·29	1·62	Caking.
Barakar (Kurasia) .	2*	1·299	11·45	34·50	54·05	1·56	Non-caking.
Barakar (low fuel-ratio) .	5	1·332	14·03	41·60	44·37	1·07	Non-caking.
Barakar (high fuel ratio)	19†	1·268	1·89	33·55	64·56	1·97	Caking.

* Adjusted by transferring 5 per cent. from fixed carbon to volatile matter.
† Five analyses adjusted by transferring 5 per cent. from fixed carbon to volatile matter.

From this table we see that there is no property of these vitrains that varies regularly with age. There are high and low specific gravities amongst both younger and older vitrains as also high and low moistures. There are high and low volatiles amongst both younger and older vitrains, but there is a tendency for the older vitrains to show lower volatiles and higher fixed carbon. There is consequently a tendency for the fuel-ratio to increase with age, and if the vitrains with low fuel-ratios regarded as Barakar in age should prove instead to be Upper Raniganj, then the order of fuel-ratios would correspond more closely to the order of age, the Skye analyses even as adjusted constituting the main disturbing factor.

As the table of vitrains of different ages arranged in order of age does not show any marked correlation between age and any one factor and only a minor degree of correlation between age and fuel-ratios, we must next investigate whether within one coalfield the different seams show any orderly change of specific gravity, composition or fuel-ratio with stratigraphical horizon.

For this purpose we have available analyses of vitrains from 3 seams in the Raniganj stage of the Raniganj coalfield, and from 4 seams in the Barakar stage of the same field. These are arranged in stratigraphical order in the following table (on an ash-free basis as usual)[1] :—

Stage.	No. of specimens	Seam.	Specific gravity.	Moisture	Volatile matter	Fixed carbon	Fuel ratio: Of each seam.	Fuel ratio: Mean for each stage.
Raniganj	Rr. 1	Ghusick (?)	1·269	5·90	39·50	54·60	1·38	1·34
	Rr. 2	Dishergarh	1·255	2·31	44·14	53·55	1·21	
	Rr. 3	Poniati	1·269	3·51	39·79	56·70	1·42	
Barakar	Rb. 1	Begunia	1·262	1·81	36·88	61·31	1·66	1·93
	Rb 2	Ramnagar	1·260	1·63	33·42	64·95	1·94	
	Rb. 3	Laikdih	1·268	1·33	32·38	66·29	2·05	
	Rb. 14	Damagaria	1·255	1·06	32·01	66·92	2·09	

[1] The two analyses of Rr. 4 representing the Samla seam in the Raniganj stage are not used in this table as this seam occurs in the extreme north-eastern part of the field between which tract and the middle portion of the field, where the Ghusick, Dishergarh and Poniati seams are worked, there is considerable lateral variation. According to Mr. Gee (in a letter to me) the evidence available over this intervening area is insufficient to allow of an unquestionable correlation. Mr. Gee considers, however, that it is definitely proved that the Samla seam is the bottom seam of the Raniganj stage in this north-eastern portion of the field, but that it should be correlated with a horizon in the series approximating to that of the Dishergarh seam in the west, the lower seams having died out to the north-east.

Although this series of figures does not display complete regularity, yet, on the whole, there is a definite sequence amongst these 7 seams. In the Barakar stage the increasing stratigraphical depth is accompanied by a regular decrease of moisture and volatile matter and an increase of fixed carbon and fuel-ratio. The Raniganj seams illustrate the same points much less regularly, the moisture tending to increase in depth and the fixed carbon to increase; but the volatile matter behaves very irregularly and consequently the fuel-ratio also.[1] Nevertheless, the series of 7 seams, regarded broadly, show decreasing moisture and volatile matter and increasing fixed carbon and fuel-ratio with depth. The specific gravities are rather irregular, but on the whole follow the moistures and decrease in depth, the stratigraphically highest vitrain showing a specific gravity of 1·269 and the stratigraphically lowest a specific gravity of 1·255. (The Samla vitrain not taken into account shows a specific gravity of 1·300.)

A series of analyses is also available for vitrains from 3 Raniganj and 3 Barakar seams in the Jharia field. The series is as follows :—

Stage.	No. of speci-mens.	Seam.	Specific gravity.	Mois-ture.	Volatile matter.	Fixed carbon.	FUEL RATIO	
							Of each seam.	Mean of each stage.
Raniganj	..	Lohpiti	1·264	2·37	38·24	59·39	1·55	1·62
	..	Barunga	1·256	2·38	37·85	59·77	1·57	
	..	Huntodih	1·295	3·07	35·22	61·71	1·75	
Barakar	Jh. 13	Seam 17	1·280	2·30	33·63	64·42	1·91	1·84
	Jh. 11	Seam 17	1·275	1·83	33·75	65·73	1·91	
	..	Seam 14	1·268	1·61	36·33	62 06	1·71	
Karharbari	Gd. 1	Lower Karharbari.	1·258	0·65	36·58	62·57	1·71	1·71

The Karharbari specimen is from the Giridih field. The Raniganj data are irregular, but in the Barakar stage there is a decrease of specific gravity and moisture with depth; in general the volatile matter, fuel-ratios, and fixed carbon are irregular, with the average

[1] This irregular behaviour on the part of the vitrains from these seams in the Raniganj stage may be due to the fact that the localities from which the specimens were obtained are scattered about the middle and western portion of the field, instead of being from one compact area, as is the case of the 4 Barakar seams, the vitrains of which were all taken within a mile or two of each other.

fixed carbon higher in the lower stage (Barakar) than in the upper (Raniganj).

According to Hilt's law, as worked out for the coalfield of the Pas de Calais, decreasing volatile matter and increasing fixed carbon is to be expected in the successive seams in one field, so that the fuel-ratio (based on proximate analysis), or the carbon-ratio (based on ultimate analysis) should increase with depth, in other words a series of coals should show increased degree of carbonisation with stratigraphic depth. On the whole, the above figures illustrate this. In the Pas de Calais, this progressive variation is ascribed to metamorphism subsequent to deposition,[1] but Strahan and Pollard in their Memoir on 'the Coals of South Wales'[2] pointed out that for South Wales the increasing anthracitization with depth is a necessary accompaniment of the formation of anthracite at successive intervals at a more or less constant distance from a retreating shore-line.

The lack of any regular change in accordance with age as shown in Table 7 supports the possibility that differences between the vitrains of different fields in India may be at least in part, functions of original differences dating from the time of deposition. Consequently, the variations from seam to seam in one field may also be due, at least in part, to original differences dating from the time of formation rather than to subsequent metamorphism brought about either by horizontal thrust or by the weight of the superincumbent load. That the latter may not have had much effect is shown by the way in which seams low down in the Barakar series tend to show, parallel with their smaller moisture, a smaller specific gravity than seams above. Whereas metamorphism should cause a decrease in the moisture, it should also cause an increase in the specific gravity of vitrain. That coals are at least sometimes completely formed soon after the time of original deposition of the vegetable matter is illustrated by the following quotation concerning the Tertiary coal of Skye :—

"The constitution of the vegetable matter before the advent of the overlying lava is difficult to deduce, but if the change in the surface of the upper seam is really a form of coking it looks as if this

[1] F. Reeves, in a recent paper 'The carbon-ratio theory in the light of Hilt's Lw,' *Bull. Amer. Assoc. Pet. Geologists*, Vol. 12, pp. 1928, discusses Hilt's Law on the basis that chemical transformations of carbonaceous deposits have taken place subsequent to deposition, but concludes that these transformations are due not so much to heat and pressure incident to horizontal thrust, as to heat and pressure incident to depth of burial.

[2] *Mem. Geol. Surv. England & Wales*, 2nd Edition, p. 85 (1915).

vegetable matter must already have been somewhat compacted and on the way to coal before the lava was erupted."[1]

The deduction, based on specific gravity values, that the vitrains of the Barakar seams, for instance, acquire their differences at least in part at the time of deposition agrees with the deduction already drawn for the coal of Skye, and with the conclusions of Strahan and Pollard relative to the bituminous and anthracitic coals of South Wales.

Another point to which attention may be directed is that all the vitrains considered in this paper may be regarded as bituminous coals if one follows the classification based on fuel-ratio adopted by the Pennsylvania Geological Survey (*loc. cit.*, p. MM. 144) and summarised by Strahan and Pollard (*loc. cit.*, p. 60) as follows :—

	Fuel-ratio.
Anthracite	12 and over.
Semi-anthracite	8 to 12.
Semi-bituminous	5 to 8.
Bituminous	0 to 5.

All the vitrains considered in this paper have fuel-ratios between 0·85 and 2·76. Lignites might also show similar fuel-ratios, but none of the specimens tested showed lignitic structures, and without ultimate analysis it is impossible to say whether any of these vitrains should be regarded as lignites. In the absence of such information, they may all be regarded for the present as bituminous coals, even when Tertiary in age. I must note, however, that the Tertiary coal of Skye is regarded by Heddle[2] as lignite and that Harker, in his "Tertiary Igneous Rocks of Skye" (p. 10), follows Heddle.

VI. THE CHANGE OF COMPOSITION OF VITRAIN ON KEEPING.

In the course of his chemical study of the coals of South Wales, Dr. Pollard made experiments to ascertain the extent to which the composition of coal is affected by keeping. He re-analysed one anthracite, one steam coal and two bituminous coals after intervals

[1] *Rec. Geol. Surv. Ind.*, Vol. LX, p. 361 (1928).
[2] Mineralogy of Scotland, Vol. II, p. 183 (1901).

of 4 years in 3 cases and 5 years 7 months in the 4th case. He found the following changes :—

Loss of carbon	(·02)	0·24	1·39	0·96
Gain in specific gravity of pure coal[1]	(·007)	0·013	0·026	0·020

In addition, all the analyses show a trivial fall in hydrogen and a definite increase in oxygen.

Dr. Pollard's data are in ultimate analyses. The available data relative to change of Indian vitrains are in proximate analyses. The case of rapid alteration of 'jet' from Kashmir is discussed on pages 209-210. The direction of change is of decreased specific gravity, the reverse of the direction for the coals of South Wales. Fixed carbon and fuel-ratio fall in the Kashmir vitrain, and may be compared with the loss of carbon and usually increased carbon-ratio in the South Wales coals.

In order to investigate whether the change of crucible and other causes referred to on pages 193-194, had really had the effect of causing a difference between the results of determination of volatile matter and fixed carbon at earlier and later dates two of the Bokaro vitrains were re-analysed ; and at an earlier date the Kurasia vitrain had already been re-analysed. In addition, several of the specimens investigated in 1928 were analysed twice. In every case of re-analysis, fresh material was selected from the original specimen for the second analysis, in order to permit of the redetermination also of the specific gravity upon the vitrain before powdering. The following table shows the data available (reduced to an ash-free basis in the usual way) to illustrate change of specific gravity and composition with time.

[1] Obtained by deducting 0·01 for each 1 per cent. of ash from the specific gravity as determined. See footnote 2, p. 190, *loc cit.*, pp. 43-45.

TABLE 11.—*Data illustrating the change of specific gravity and composition of Indian vitrains with time.*

Coalfield or region.	Horizon.	No. of specimen.	Date of analysis.	Specific gravity.	Moisture.	UNADJUSTED.			ADJUSTED.*		
						Volatile matter.	Fixed carbon.	Fuel ratio.	Volatile matter.	Fixed carbon.	Fuel ratio.
Bokaro	Barakar	23·996	7-3-17	1·252	1·24	28·47	70·29	2·47	33·47	65·29	1·95
			25-7-19	1·260	2·04	28·12	69·84	2·48	33·12	64·84	1·96
			22-9-28	1·280	2·34	29·90	67·76	2·26	29·90	67·76	2·26
			3-11-28	1·282	2·43	29·30	68·27	2·33	29·30	68·27	2·33
Bokaro	Barakar	23·926	16-7-19	1·264	2·32	30·95	66·73	2·16	35·95	61·73	1·72
			3-11-28	1·281	2·62	34·78	62·60	1·80	34·78	62·60	1·80
Kurasia	Barakar	26·669	4-5-13	1·295	9·85	29·33	60·82	2·07	34·33	55·82	1·62
			8-8-19	1·303	13·06	29·66	57·28	1·93	34·66	52·28	1·51
Jharia	Barakar	Jh. 13	25-5-28	1·289	2·07	35·20	62·73	1·78			
			6-10-28	1·280	2·30	33·63	64·07	1·91			
Raniganj	Raniganj	Hun-todih.	25-9-28	1·295	3·07	35·22	61·71	1·75			
			11-10-28	1·294	3·30	34·46	62·24	1·80			
Raniganj	Raniganj	Rr. 1	17-2-28	1·267	5·44	40·14	54·42	1·35			
			22-9-28	1·271	6·35	38·87	54·78	1·41			
Raniganj	Raniganj	Rr. 4	17-2-28	1·291	9·65	38·35	52·00	1·36			
			22-9-28	1·309	12·95	34·71	52·34	1·50			
Cherrapunji	Eocene	Sh. 6	17-12-28	1·269	0·91	46·17	52·92	1·15			
			14-1-29	1·272	0·96	44·21	54·83	1·24			
Punjab	Siwalik	Sw. 1	25-5-28	1·327	7·66	41·75	50·59	1·21			
			22-9-28	1·362	8·14	37·98	53·88	1·42			

* By transferring 5 per cent. from fixed carbon to volatile matter in analyses made in 1913, 1917 and 1919.

In the case of analyses made in 1913, 1917 and 1919, a transference of 5 per cent. from fixed carbon to volatile matter is made in the final three columns to allow for the presumed effect of the change of crucible discussed on pages 193-194. In studying the above data the adjusted data for the first three specimens should be compared with the unadjusted data for the remaining 6. Using the adjusted data for the first three analyses, the changes indicated are as follows :—

Horizon.	Barakar.				Raniganj.			Eocene.	Siwalik.
Number of specimen.	23·996	23·926	26·669	Jh. 13	Huntodih.	Rr. 1	Rr. 4	Sh. 6	Sw. 1
Specific gravity.	+0·030	+0·017	+0·008	—0·009	—0·001	+0·004	+0·018	+0·003	+0·035
Moisture .	+1·19	+0·30	+3·21	+0·23	+0·23	+0·91	+3·30	+0·05	+0·48
Volatile matter	—4·17	—1·17	+0·33	—1·57	—0·76	—1·27	—3·64	—1·96	—3·77
Fixed carbon	+2·98	+0·87	—3·54	+1·34	+0·53	+0·36	+0·34	+1·91	+3·29
Fuel ratio .	+0·38	0·08	—0·11	+0·13	+0·05	+0·06	+0·14	+0·09	+0·21
Time during which change occurred.	11·8 y	9·4y	6·3y	4 m.	16 d.	7 m.	7 m.	27 d.	4 m.
Low or high moisture.	l. m.	l. m.	h. m.	l. m.	m. m.	h. m.	h. m.	l. m.	h. m.

These data suggest a reasonable uniformity of direction of change. The most constant change and one that is shown by all the specimens is an increase of moisture with time. The amount of this increase is small in the case of low-moisture vitrains, whether considered over a long period (1·19 per cent. in 11¾ years) or a short period (0·05 per cent. in somewhat less than a month), but is considerable in some high-moisture vitrains (3·21 per cent. in 6 years in one case, 3·30 per cent. in 7 months in a second case, 0·91 per cent. in 7 months in the third case). In all, except two cases, there is a concurrent increase of specific gravity. The smaller increases may be regarded as possibly within the limits of experimental error, but the larger increases can hardly be so regarded. In two cases there is a decrease of specific gravity, the amounts being 0·009 and 0·001, respectively. The latter of these is certainly within the number of experimental error and applies to a period of only two weeks.

In volatile matter, fixed carbon and fuel-ratio, the six pairs of recent analyses are in remarkable agreement. They all show decrease of volatile matter with time, increase of fixed carbon and increase in fuel ratio. The first three sets of analyses, before adjust-

ment of the earlier figures, show results which, as a whole, are the reverse of those shown by the six later sets, namely, increase of volatile matter, decrease of fixed carbon and decrease of fuel-ratio with time. But though the four analyses of 23·996 show an increase of volatiles from the earlier pair to the later pair of analyses, yet each pair shows a decrease of volatiles as with the six pairs of later analyses already discussed. After adjustment, however, in the manner mentioned, the figures for these three sets of analyses, although not in complete agreement with those of the later six, yet on the whole tell the same story.

It will be seen that the vitrains illustrating these changes come from four different geological horizons.

VII.—THE COLLOIDAL NATURE OF VITRAIN.

In a previous paper it was shown that coals of the vitraindurain series are colloid systems in which the ash content is present as the disperse phase and the fundamental coal substance or vitrain is present as the dispersion medium.[1] It was further suggested[2] that the vitrain itself is a colloid system of the emulsoid or gel type in which it is uncertain whether the moisture or the complex of carbon compounds (*i.e.*, moisture-free vitrain) acts as the dispersion medium.

It was hoped that the present investigation would throw light upon this latter suggestion. A study of the curves in Plates 1-4 does not, however, do so. The only general conclusion is that, on the whole, moisture and specific gravity tend to increase together. Volatile matter and fixed carbon do not always move in the same direction either as the specific gravity or each other. One can, however, probably with some approach to the truth, draw from these curves the conclusion that the moisture-free vitrain contains two general series of compounds, one of which yields the major part of the volatile matter and the other of which yields the major part of the fixed carbon. The latter series is presumably a series of highly unsaturated compounds rich in carbon and poor in hydrogen, easily decomposed on the application of adequate heat so as to yield a large percentage of free carbon and a smaller percentage of volatile matter,

[1] *Rec. Geol. Surv. Ind.*, LX, p. 347.
[2] *loc. cit.*, p. 348.

which is added to the volatile matter provided by the other series of carbon compounds. It is possible that a portion of the carbon of the series that provides the major part of the fixed carbon is present in the elementary condition, and specimens have been handed to Professor Raman to enable him to attempt to determine by X-ray methods whether this is the case, it being thought that possibly such free-carbon might be present in a colloidal state of sub-division.

As regards the 'moisture' it might be present in one of three ways :—

(1) In combination with the moisture-free vitrain.

(2) In colloidal association with moisture-free vitrain.

(3) Mechanically entangled with the moisture-free vitrain.

The data obtained during the present investigation do not enable one to distinguish between possibilities (1) and (2), but it is possible to investigate (3) by comparing vitrains of similar fuel-ratio but different specific gravity and moisture. The following 3 pairs taken from Table 7 may be used :—

Coalfield.	Stratigraphical horizon.	Specific gravity, *k*.	Moisture	Volatile matter.	Fixed carbon.	Fuel ratio.
Giridih	Barakar .	1·258	0·85	36·58	62·57	1·71
South Karanpura . .	Barakar .	1·289	6·37	34·50	59·13	1·71
Makum . . .	Miocene .	1·236	1·56	45·13	53·31	1·22
Talcher . . .	Barakar .	1·323	15·17	38·81	46·02	1·18
Lairangao . . .	Eocene .	1·230	1·65	50·18	48·17	0·96
Sohagpur . . .	Barakar .	1·300	10·00	45·85	44·15	0·96

Taking the data for the first member of any pair it is possible to calculate the figure to which the specific gravity should increase if sufficient moisture were absorbed into assumed pore space to raise the total moisture to that of the second member of the pair without increase of volume above that of the first member of the pair. Treated in this manner the specific gravity of the second member of each pair should be as follows, the figures in brackets being the actual specific gravity :—

South Karanpura	1·332	(1·289)
Talcher	1·434	(1·323)
Sohagpur	1·344	(1·300)

This means that the high-moisture member of each pair cannot be regarded as derivable from the low-moisture member by absorption of moisture without increase of volume. On the other hand, we cannot regard the high-moisture member of each pair as derivable from the low-moisture member by mere mechanical admixture of water, for clearly the specific gravity of the system would then fall. Instead the specific gravity is higher, so that we can regard the high-moisture vitrains as having contracted with reference to the total volume of moisture-free vitrain plus moisture, but as swollen with reference to the volume of moisture-free vitrain alone. These data indicate some intimate association between the moisture and the moisture-free vitrain, and one may presume the association to be colloidal, especially as these relations are those characteristic of a gel. Thus, quoting Freundlich [1] :—

"Swelling is accompanied by a nett decrease in volume, that is, the sum of the original volumes of the dry gel and of the liquid is greater than the volume of the swollen gel."

Assuming that the secular changes indicated by the data given on page 218 in accordance with which both moisture and specific gravity increase with time do actually occur, it may be of interest to see what is the nature of the volume change. We may take two different types of pairs, one in which there has been a small total increase of moisture over a long period, and the other in which there has been a large total increase over a short period :—

Coalfield.	Horizon.	Date of analysis.	Specific gravity. g	Moisture.	Fuel ratio.
Bokaro . .	Barakar	7-3-17	1·252	1·24	1·95
		3-11-28	1·282	2·43	2·33
Raniganj . .	Raniganj	17-2-28	1·291	9·65	1·36
		22-9-28	1·309	12·95	1·50

These cases are not as simple as the others just considered, because the secular change has been accompanied by changes of volatile

[1] N. Freundlich. 'Colloid and Capillary Chemistry ;' translated from the third German edition by N. Stafford Hatfield, 1926, p. 673. See also pp. 714 and 715, where the volume contraction of casein on imbibition of water is given. Reference may also be made to a paper by F. M. Lea, 'Some Physico-Chemical Properties of Coal,' *Fuel*, VII, p. 442 (1928).

matter and fixed carbon with increase of fuel-ratio. The latter possibly means that there has been an absolute loss of volatiles with possibly an addition of a part of the carbon of the lost volatiles to the fixed carbon. We have, however, no means of allowing for this and must see what the volume change is on the assumption of constancy of fuel-ratio.

A similar calculation to the previous shows that in these two cases the addition of moisture to the first of each pair sufficient to raise the percentage to that of the second of each pair without increase of volume would cause an increase of specific gravity to the following figures—those in brackets being the actual specific gravity of the second in each pair :—

Bokaro	1·267	(1·282)
Raniganj	1·352	(1·309)

that is, to a figure only half way between the two actual specific gravities in the Bokaro case, but to a much higher figure in the Raniganj case, the latter being similar to the cases already considered. The latter change, if we take no notice of the change of fuel-ratio, means, as before, swelling with reference to the original volume of the vitrain and condensation with reference to the volume of vitrain plus added moisture; whilst in the Bokaro case, there has been actual contraction with reference not only to the volume of the vitrain plus added moisture, but also with reference to that of the original vitrain also. In view of the change of fuel-ratio, however, the latter cannot be assumed to have actually occurred.

VIII.—SUMMARY AND CONCLUSIONS.

1. In a previous paper it was shown that in two sets of coals of the vitrain-durain series obtained respectively from the Kurasia and Bokaro coalfields, the relationship between specific gravity and ash contents of any specimen is expressed by the rule :

$$a=100\ (g-k),$$

in which a is the ash contents, g the specific gravity of the specimen, and k the specific gravity of ash-free coal (*i.e.*, pure vitrain) for the field.

2. Analyses of specimens of vitrain from several different localities suggested that the value of k must vary from field to field, and that on the whole k increases with moisture contents.

3. A considerable number of specimens of vitrain from various Indian sources has now been collected and analysed in order to determine what variations in proximate composition accompany variation in the specific gravity of vitrains (See pp. 196-202).

4. The specimens examined come from the following stratigraphical horizons :—

Barakar (12 coalfields, 25 analyses).
Raniganj (2 coalfields, 9 analyses).
Eocene (2 coalfields, 4 analyses).
Miocene (2 coalfields, 6 analyses).
Siwalik (Kashmir and Punjab, 8 analyses).

5. The analyses and specific gravities as determined are shown in Tables 1 to 6. In addition the specific gravity of pure ash-free vitrain is in each case deduced by subtracting 0·01 from the specific gravity as determined for each 1 per cent. of ash present, as is obviously possible if the rule stated in paragraph 1 above is applicable.

6. These data, with the figures of moisture, volatile matter and fixed carbon reduced to an ash-free basis are shown in the same tables, and it is these figures on an ash-free basis that are used throughout the paper as a basis of discussion.

7. In 1928, a different crucible was used from that in the earlier years (1907 to 1919), and this change appears to have led to values for volatile matter and fixed carbon different in the earlier years from those obtained in later years. For purposes of comparison, therefore, an adjustment is made in the few earlier analyses by transferring 5 per cent. from the fixed carbon to the volatile matter (see p. 203).

8. In Table 7, the ash-free data are represented by average figures for each field and stage, arranged in order of k, the specific gravity of ash-free vitrain for each field as thus deduced.

9. The data in Tables 1 to 6 are plotted in Plates 1 to 3, the ordinates in each plate being specific gravity, whilst moisture, volatile matter, fixed carbon and fuel-ratios appear as abscissæ. The data for the Barakar stage are plotted in Plate 1, for the Raniganj stage in Plate 2, for the Tertiary coals (Eocene, Miocene and Siwalik) in Plate 3, whilst the data for all the high-volatile fuels are plotted together in Plate 4.

10. Inspection of these plates shows that in every case the moisture increases with specific gravity either regularly or in steps. Taking all the data used, the limits of moisture are 0·63 and 16·61 per cent. and the limits of specific gravity are 1·214 (moisture, 2·25 per cent.) and 1·414 (moisture 15·15 per cent.) (see Tables 1 to 6).

11. The volatile matter increases with the specific gravity in the Barakar vitrains, decreases in the Raniganj and Eocene vitrains, first increases and then decreases in the Miocene vitrains, decreases and then increases in the Siwalik vitrains. (See Plates 1 to 3.)

12. The fixed carbon in all cases changes in the reverse manner to the volatile matter as detected in paragraph 11.

13. The fuel-ratios decrease with increase of specific gravity in the Barakar vitrains and tend to do so with the Siwalik vitrains; in all other cases—Raniganj, Eocene and Miocene—the fuel-ratios increase slightly with specific gravity (see Plates 1 to 3).

14. As regards caking properties, most vitrains cake if they contain less than 9 to 10 per cent. of moisture, and do not cake with moisture in excess of this figure. But there is no correlation between caking properties and either volatile matter, fixed carbon or fuel-ratio. (Plates 1 to 3.)

15. In the vitrains from the Barakar stage the lustre varies with the moisture contents, the low-moisture vitrains being the most brilliant, and the high-moisture vitrains the dullest. In vitrains from other sources the correlation between lustre and moisture contents is not so close (see p. 211).

16. The Barakar vitrains can be divided into two groups, the normal type with lower specific gravity and moisture and higher fuel-ratio (caking vitrains), and the less normal types with high moisture and specific gravity and lower fuel-ratio (non-caking vitrains). The latter are mainly found outside the Damodar valley (Talchir, Rajmahal, Sohagpur, Kurasia), and one wonders if the fossil flora of these outlying occurrences justifies the assumption that they are Barakar in age. A somewhat higher horizon would be more consonant with the data. (See p. 206.)

17. Further a vitrain from the supposed Barakars of the Kurasia field, Korea State, is so similar in analysis (after adjustment), specific gravity and fuel-ratio to a vitrain from the Raniganj stage in the Raniganj field, that one wonders if the Barakar attribution can be correct (see p. 207).

18. Arrangement of the vitrain data in order of stratigraphical position does not reveal any orderly progression of properties and one wonders if age is an important factor in producing differences in coals or whether differences are not largely a function of original differences of deposition—either of conditions or of material deposited. (See pp. 212-216.)

19. Within one coalfield—*e.g.*, Raniganj or Jharia--vitrain analyses tend to show an orderly progression if arranged in stratigraphical sequence. In fact, they tend to follow Hilt's law of increasing carbonization with stratigraphic depth : the fixed carbon and fuel-ratios tend to increase, and specific gravity, moisture and volatile matter to decrease with stratigraphic depth. If this sequence had been caused by metamorphism due to the superincumbent load, one would expect the specific gravity to increase with increasing stratigraphic depth ; instead the tendency is for there to be a decrease. This leads one to suggest that even in the case of the Raniganj and Barakar vitrains obeying Hilt's Law, the somewhat regular differences are functions of some gradual change of conditions of original deposition rather than due to subsequent change. This is analogous to the view of Strahan and Pollard that progression in the degree of anthracitization of the coals of South Wales is due to a gradual change of conditions of deposition rather than to subsequent metamorphism.

20. One specimen of Kashmir vitrain changed composition rapidly during a period of only three months as detected by a series of three analyses. The changes were in the direction of substantial decrease of specific gravity (1·414 to 1·275), and moisture (15·15 to 9·89 per cent.) and fixed carbon (46·06 to 33·38 per cent.), and increase of volatile matter (38·79 to 56·73 per cent.). (See p. 209.)

21. Several other specimens from various stratigraphical horizons and localities that were analysed twice (or in one case four times) showed with some consistency changes the reverse of those shown by the Kashmir vitrains, but on a much smaller scale. The changes were increases in specific gravity (maximum 0·030), moisture (maximum 3·30 per cent.), fixed carbon (maximum 3·29 per cent.) and fuel-ratio (maximum 0·38), and a decrease in volatile matter (maximum 4·17 per cent.). (See pp 216-20.)

22. The most remarkable fact illustrated by this investigation is the increase of specific gravity with moisture. This applies irrespective of age of coal and can be observed either by comparing specimens of different specific gravities and moisture or by observing the changes in specific gravity and moisture of one specimen on keeping. Thus one specimen of Kashmir Siwalik vitrain decomposed with loss of water on keeping; the specific gravity also decreased. All the other vitrains showed increase in moisture on keeping; the specific gravity almost invariably increased.

23. Calculations made to see whether the increase of specific gravity of vitrain with increasing moisture could be accounted for on the assumption that the moisture is taken into assumed pore space in the vitrain (of either molecular, colloidal or larger dimensions) without causing change of the volume of the vitrain show that if this happened, the increases of specific gravity would be much greater than has been found. It is found on comparing analyses of a high-moisture and low-moisture coal of the same fuel-ratio that the high moisture vitrain occupies less space than would be occupied by the low-moisture vitrain plus the additional moisture, but more space than the low-moisture vitrain alone. Hence, if we could imagine the low-moisture vitrain passing into the high-moisture vitrain by absorption of water, the absorption would be accompanied by a swelling with reference to the volume of the low-moisture vitrain, but a condensation with reference to the volume of low-moisture vitrain plus additional water. (See pp. 220-23.)

24. In the previous investigation it was shown that durain must be regarded as a colloid system in which there are two disperse phases, namely ash contents (suspensoid) and vegetable detritus (coarse suspension), in vitrain as the dispersion medium. Vitrain itself being an obvious colloid, it was thought that the comparative study of vitrain undertaken in this paper and the construction of concentration-density diagrams might lead to definite suggestions concerning the phases present in the vitrain itself. It was thought, for instance, that vitrain might prove to be a colloid system of moisture and moisture-free vitrain and that the latter might prove to be a colloid system of two groups of carbon compounds, one of which yielded the major portion of the volatile matter and the other the major portion of the fixed carbon on heating. It was even thought that a portion of the fixed carbon might prove to be present as free carbon in a state of colloidal disperson.

25. A study of the density-concentration diagrams seems to demonstrate that there must be two series of compounds in vitrains of the respective nature suggested in the previous paragraph. But the data do not enable one to say that their relationships are colloidal and this can remain only a matter of surmise as far as this study is concerned.

26. The same might be thought to be the case with moisture, *vis-a-vis* moisture-free vitrain ; but the fact that the volume relationship between two vitrains of widely different moistures but identical

fuel-ratios is such that if the low moisture vitrain could be converted into high moisture vitrain by addition of the necessary moisture, the volume change would be one of swelling with reference to the volume of the low moisture vitrain but contraction with reference to the volume of the low-moisture vitrain plus added water, enables us to institute a comparison with the case of a dry gel (*e.g.*, casein) imbibing water with exactly similar volume changes. We seem warranted therefore in concluding that in vitrains we are dealing with systems in which the relationship of moisture to moisture-free vitrain is a colloidal relationship (see p. 223). It is not suggested that it is feasible in practice to convert a low-moisture vitrain into a high-moisture vitrain, by soaking it in water. The fact that all the analyses given in this paper have been made on material that has been soaked in water for the purpose of determination of the specific gravity, shows that this is not so; indeed, the fact that vitrains from different sources retain their own general amount of moisture in spite of the treatment to which they have been subjected (that is, conditions of storage, humidity and temperature of atmosphere) suggests that the major portion of the moisture of vitrain is not hygroscopically present, but is associated with vitrain in a more intimate manner so that the vitrain must be regarded as a gel which will not suffer complete desiccation under atmospheric conditions, but retains a certain minimum amount of water which varies with the coal itself. What the difference in structure or composition is that causes two sets of vitrains of identical fuel ratio to retain, the one only 1·65 per cent. of moisture and the other as much as 10 per cent., under identical climatic conditions, is not brought out in this investigation.

LIST OF PLATES.

NEW DEVONIAN FOSSILS FROM BURMA. BY F. R. COWPER REED, SC.D.(CANTAB)., F.G.S. (With Plates 5 to 8.)

An Upper Devonian Fauna from the neighbourhood of Padaukpin, Northern Shan States.

The locality from which Mr. LaTouche obtained the collection of Middle Devonian fossils described by the present author in 1908 [1] was stated to be close to the western gate of the village of Padaukpin, and the general facies of the fauna as well as the occurrence of many well-known European species led to the conclusion that the horizon was that of the Calceola stage of the Middle Devonian.[2]

In the course of the author's visit to the Shan States in 1927 a new exposure of a lithologically similar limestone was discovered in a small stream-course on the jungle-clad slopes which descend steeply to the Kelaung Chaung valley about 3 miles S. S. E. of Padaukpin village. The solid rock here largely consists of masses of corals (*Phillipsastræa*, etc.) and in the stream bed and on its banks loose specimens of brachiopods and occasional isolated corals are found weathered out and mostly in a good state of preservation. The lithological character of the rock and condition and mode of preservation of the fossils are identical with those of the other occurrence at Padaukpin, but the assemblage of fossils is quite different, as is pointed out below, and another horizon is certainly represented. Two visits which I paid to this locality accompanied by Mr. Peter Leicester of the Geological Survey of India resulted in the collection of a considerable series of specimens, amongst which are the new species or varieties described below. The exact locality is exceedingly difficult to find, as it is in the midst of thick jungle some distance from any native cart-road or foot-path, and the many small water-channels amongst the trees are so closely similar in appearance that it is hard to locate the single fossiliferous one. The whole portion of the stream-course from which the specimens were

[1] Reed : *Palæont. Indica,* New Ser. Vol. II, Mem. 5, 1908, pp. 1-157, pls. I-XVII.
[2] LaTouche ; *Mem. Geol. Surv. India,* Vol. XXXIX, Pt. 2, 1913, pp. 196-241.

collected is not more than 15 yards in length, and above and below this stretch no trace of fossils could be found.

List of Species.

Phillipsastræa orientalis sp. nov. (Stanley Smith).
,, *padaukpinensis* sp. nov.
Endophyllum cf. *priscum* (Münst).
Cyathophyllum ceratites Goldf. ?
Striatopora cf. *angulosa* Gürich.
,, cf. *Tchichatschewi* Von Peetz.
,, cf. *Suessi* Penecke.
Alveolites suborbicularis Lam.
,, *ramosa* Roem.
Aulopora serpens Goldf. ?
Favosites vicina sp. nov.
Orthis (*Schizophoria*) *striatula* Schloth.
,, ,, *Ivanovi* Tschern.
,, ,, cf. *hainensis* Maur.
,, (*Dalmanella*) *tioga* Hall.
Stropheodonta (*Douvillina*) *imitatrix* sp. nov.
Orthothetes (*Schellwienella*) *umbraculum* Schloth.
Atrypa reticularis Linn. var. nov. *subauriculata.*
,, *Douvillei* Mansuy, var.
Spirorbis omphalodes Goldf.

GENERAL CHARACTER OF THE FAUNA.

The chief features of the fauna collected from this locality are the presence of large masses of the coral *Phillipsastræa*, and the abundance of the three brachiopods, *Douvillina imitatrix* sp. nov., *Orthothetes umbraculum* and *Atrypa reticularis* var. nov. *subauriculata.* The other fossils are only represented by a few or by single specimens.

We may note that there is a complete absence of such typical fossils as *Calceola sandalina*, *Stropheodonta interstrialis*, *Rhynchonella* (*Hypothyris*) *cuboides*, *Strophonella caudata* and the numerous other brachiopods and bryozoans which characterised the previously described occurrence of Devonian limestone at Padaukpin.

In fact the only species common to the two localities are the following: *Orthis* (*Schizophoria*) *striatula*, *Alveolites ramosa*, *A. suborbicularis*, *Spirorbis omphalodes* and possibly *Aulopora serpens* and

Cyathophyllum ceratites. None of the species of corals is identical, and there is an absence of lamellibranchs, gasteropods, cephalopods and trilobites. The positive evidence is, however, sufficient to indicate a different horizon and it will be seen that the relationships of the species point to the lower part of the Upper Devonian rather than to the Middle Devonian.

Grabau [1] in describing the Devonian beds of China refers to the author's memoir on the Middle Devonian fossils of Padaukpin and remarks that there are many representatives of the Givetian in the fauna, though the typical *Stringocephalus Burtini* was not found.

In the present collection we see evidence of a still higher Devonian fauna, and there is an absence of the characteristic members of the Calceola and Stringocephalus horizons. Mansuy [2] has described a Givetian fauna mixed with Upper Devonian elements from several localities in Yunnan, but it does not seem that any of the species in the new collection from Padaukpin are represented, except perhaps some of the ubiquitous and variable species of *Atrypa*, and a species of *Douvillina.* The genus *Phillipsastræa* has been found by Mansuy,[3] but on the other hand *Stringocephalus Burtini* which he records is not present in our collection.

Phillipsastræa orientalis sp. nov. Stanley Smith.

Plate 5, figs. 1-3.

Several large masses of the coralla of a species of *Phillipsastræa* a foot or more in diameter were observed *in situ* in the rocks of the water-course where the other fossils were collected, and portions of them which were brought back have been submitted to Dr. Stanley Smith who considers that the species is allied to the Upper Devonian *P. hennahi* Lonsdale, which Frech [4] described in detail. Dr. Stanley Smith, [5] who has recently redefined Lonsdale's species from a study of the original specimens, considers that our Padaukpin form should be separated from it and placed in a new species which he

[1] Grabau ; "Stratigraphy of China," Part I (*Geol. Surv. of China,* 1923-24), pp. 156, 157.

[2] Mansuy, *Bull. Serv. Géol. Indochine,* Vol. VI, fasc. VI, 1919, pp. 43-45 ; *ibid.,* Vol. VII, fasc. III, 1920, pp. 8-14.

[3] Mansuy, *Mem. Serv. Géol. Indochine,* Vol. I, fasc. 2, 1912, p. 49.

[4] Frech, *Zeitschr. deut. geol. Gesell.* XXXVII, 1885, p. 59, t. V ; Lebedew, *Mem. Com. Géol. St. Petersb.,* Vol. XVII, No. 2, 1902, pp. 97, 154.

[5] Stanley Smith, *Quart. Journ. Geol. Soc.,* Vol. LXXII, 1916, p. 288, pl. XXII, figs. 1-4.

terms *orientalis*. All of our specimens have the upper surface more or less weathered and as a result the internal structure of the corallum is etched out, while round the broken edges of the corallum weathered lateral surfaces show vertical sections of the interior. According to Dr. Stanley Smith the mistaking of weathered surfaces for true distal surfaces has led to many misleading descriptions of members of this genus, but the true interpretation is often difficult. In our specimens the general distal surface of the corallum and of the corallites themselves is flat, but in each corallite there is a shallow saucer-like circular median depression, from one half to two-thirds the diameter, with a low rounded rim scarcely or not at all elevated above the general surface and belonging entirely to the extra-thecal region; the central boss which rises in the middle of the saucer corresponds with the entire intrathecal region, (as described by Stanley Smith (*op. cit.*) in the case of the type of *P. hennahi*), and it shows the major septa as crenulations on its flanks, but the centre is smooth and occupied only by the tabulae. The corallites on the weathered surface are mostly indistinctly separated from each other and have no definite walls or boundaries, the slightly flexuous septa, which in all number 32-36, being continuous and confluent without any visible epitheca.

Dr. Stanley Smith in the notes which he has kindly furnished in connection with these Padaukpin specimens states that "the Devonian genus *Phillipsastræa* D'Orbigny, 1849, (Notes sur les Polypiers Fossiles, p. 12) embraces cerioid and thamnastræoid rugose corals in which the epitheca between the corallites is much reduced or has entirely disappeared and in which the septa of neighbouring corallites are more or less confluent. The distinguishing character of the genus lies chiefly in the form of the septa which are always dilated to a greater or less extent at the theca, and in the case of the major septa frequently at their axial edges also. Carinae are typically, although not necessarily developed. There is no axial structure, and the axial region of the corallite is occupied entirely by the tabulae. The tabulae consist of a series of horizontally disposed plates which occupy most of the intrathecal space, but these are supplemented by an outer series of smaller arched plates which slope downwards towards the axis and more or less alternate with the principal tabulae. Dissepimental tissue is extensively developed and forms the greater part of the coral tissue; the dissepiments are small and numerous."

Genotype. *Astræa hennahi* Lonsdale, Trans. Geol. Soc. Ser. 2, Vol. V, pt. 3, 1840, p. 697, pl. LVIII, figs. 3, *3a*, *3b*. Upper Devonian, Barton Quarry, St. Mary Church, Torquay.

Lectotype of *A. hennahi*, Specimen No. 6185 Museum of Practical Geology, London; described by Stanley Smith, Quart. Journ. Geol. Soc. Vol. LXXII, pt. 4, 1917, p. 288, pl. XXII, figs. 1-4.

The description which Dr. Stanley Smith gives of this new species *P. orientalis* from Padaukpin is as follows :—" The corallum is imperfectly astræiform since there are distinct traces of the epitheca remaining between the corallites. [This is very rare in most of the specimens. F. R. C. R.] The intrathecal areas measure approximately 4 mm. in diameter, and these are fairly regularly spaced at intervals of about 6 mm. There are about 16 major septa in each corallite. The septa are slender and are only slightly dilated at the theca and not at all at their axial edges. No carinae are present. The major septa extend inwards from the theca for about two-thirds of the radius of the intrathecal area, but the minor septa are very short and end at the theca. The inner tabulae are large and flat, and many of them are complete (that is, they stretch across the whole of the intrathecal space) ; the outer tabulae are small and strongly inclined. "

" *P. orientalis* differs from the genotype in having less specialised septa, these being but little dilated and entirely free from carinae, whereas in *P. hennahi* the septa are much dilated and strongly carinate."

" The specimens differ from the holotype of *P. hennahi* in the larger diameter of the intrathecal area and in the greater number of septa, but many specimens of that species are also larger and have more septa than the type possesses."

It may be added that in some of the other specimens from the Padaukpin locality we can count as many as 18 major septa, and the degree of curvature and flexuosity of the septa varies somewhat, but it does not seem possible to separate the forms. The outer tabulae are subvesicular and the dissepiments are numerous and vesicular. Portions of the same corallum and of associated coralla of this species frequently differ in the appearance of the corallites. In some the astræiform character is more marked and more perfect than in others , but the epitheca is generally hard to distinguish, the boundaries of the corallites being usually unmarked.

Mansuy[1] has recorded *P. hennahi* under the generic name *Smithia* from the Middle (?) Devonian of Ki-Kai, Yunnan, but has given no figure, and it is doubtful if he is dealing with the same species.

Phillipsastræa padaukpinensis sp. nov.

Plate 6, figs. 1, 1*a*.

There is one well-preserved complete corallum of a species of *Phillipsastræa* with an entirely different external aspect which was found by the author weathered out loose on the surface at this new locality near Padaukpin. It is subcircular and subdiscoidal in shape with a nearly flat upper surface mammillated by the circular calices which are slightly raised and exsert; an irregularly oval smaller corallum is attached to one edge of the disc. There are about 40 calices present on the upper surface of the main specimen, about 20 of which are large and of equal size, but not equidistant; towards the edges of the disc the calices tend to be smaller and closer together, in some places being nearly in contact, but the larger calices over the greater part of the corallum are from three to five times their diameter apart. The corallites themselves are irregularly polygonal in shape, but of somewhat unequal size; the greater part of the disc is composed of 15-17 such corallites, the boundaries of which are partly indicated on the surface by small pits (due to weathering) arranged irregularly in a single or double row. An epithecal growth concentrically wrinkled covers the base of the whole corallum.

No sections have been cut of this unique specimen, as it seemed unnecessary to destroy it since the weathering of the surface has so well etched out the internal structure that many of the important details can be distinguished with a lens.

Its characters may be summarised as follows:—Corallum compound, massive, subcircular, subdiscoidal; distal surface nearly flat, but mammillated by the thecae. Corallites irregularly polygonal with well defined boundaries, of subequal size over the greater part of the surface; thecae circular, gently elevated, forming a low conical rounded mamelon in the middle of each corallite with a sharp raised exsert rim and a cup-like calyx more or less deep; septa slender, 32-36 in number, nearly straight in the inner part of the extrathecal region, but more or less flexuous in the outer part, not dilated at the

[1] Mansuy, *Mem. Serv Géol. Indochine*, Vol. I, fasc. 2, 1912, p. 49

thecal margin or carinate ; major septa 16-18 in number, extending inwards across each theca for about one-third its diameter ; central region of theca small, tabulate ; minor septa end on the thecal rim, but in the extrathecal area are of the same strength and thickness as major septa ; dissepiments numerous, subequidistant. Base of corallum covered with concentrically wrinkled epitheca.

Dimensions.

Diameter of corallum	. 90-95 mm.
Height of ditto	. 30-35 mm.
Diameter of calices	. 3-5 mm.
Diameter of corallites in middle region	. 12-18 mm.

Remarks.—Dr. Stanley Smith who has kindly examined this specimen is of the opinion that it is only a peculiar form of the above described *Ph. orientalis*, and he expresses little doubt that it represents the same species. But with this conclusion I find it impossible to agree ; the raised mammillate thecae with their sharp exsert rims, the more clearly defined corallites, the straighter less flexuous and rarely confluent septa and the presence of the epitheca on the base of the corallum seem to be sufficiently distinctive characters. It seems more closely to agree with *Acervularia Troscheli* E. and H. which Frech [1] includes in his *Phillipsastræa ananas* Goldf. than with *Ph. orientalis* or *Ph. hennahi*, and the Upper Devonian species *Ph. monticola* Reed [2] from Chitral may also be compared. There is little agreement amongst paleontologists about the specific separation or synonymy of the Devonian species of *Phillipsastræa* as Frech's list of synonyms and his frequent mention of transitional forms indicate, and Dr. Stanley Smith differs from his conclusions on many points. It seems therefore desirable with our present imperfect knowledge to designate this Padaukpin form by a distinctive name.

Endophyllum cf. *priscum.* (Münster).

Several large more or less perfect weathered specimens of a simple coral, apparently identical with *Endophyllum priscum* (Münst.), which has been minutely described by Frech,[3] were collected by me from the new Padaukpin locality, one of which shows a natural longitu-

[1] Frech, *op. cit.* p. 52, t. II, fig. 1.
[2] Reed, *Palæont. Indica*, New Ser., Vol. VI, Mem. 2, 1922, p. 17, pl. III, figs. 8-10.
[3] Frech, *op. cit.* 1885, p. 76, t. VII, fig. 2, t. X, figs. 2a-c.

dinal section displaying with great clearness the typical internal structure. The European species is characteristic of the lower part of the Upper Devonian. In our best preserved specimen a transverse section shows 40-44 thin primary septa, but these seem to extend inwards only about one-third of the whole diameter instead of reaching the centre ; there is visible also the usual equal number of secondary septa about one quarter the length of the primaries. A longitudinal section shows the typical single marginal row of widely spaced large oblique convex vesicles and the numerous complete flat horizontal tabulae extending over three-fourths the diameter of the corallum.

The septa, however, seem to be shorter than is usual in *E. priscum*, for Frech states that the primaries reach the middle, but our transverse section has the centre so largely filled up with crystalline calcite that the appearance of their reduced length may be accidental or the section may be near the calyx. The Russian species of *Endophyllum* from the Upper Devonian of Kusnetzk which von Peetz [1] named *Spongophyllum Wenjukowi* is described as differing from *E. priscum* in the septa not reaching quite to the centre, and herein resembles our specimens, but the septa are fewer in number and von Peetz's figures are very poor and insufficient for comparison.

Cyathophyllum ceratites Goldfuss ? (*non* Edwards and Haine).

There is one small cornuate simple coral in the collection showing the calyx and character of the septa probably identical with this well known European species, which Frech [2] has described and figured from the upper part of the Middle Devonian of southern Yunnan ; the author [3] has previously recorded it from Padaukpin, and Mansuy [4] from the Middle Devonian of Si-tche-yi, Yunnan.

Striatopora cf. *angulosa* Gürich.

There are several weathered and poorly preserved specimens of *Striatopora* which may be compared with Gürich's species *Str. angulosa*,[5] but they seem to be distinct from the Upper Devonian

[1] Von Peetz, *Beitr. Kennt. Fauna devon. Schicht. Kusnetzk*, 1901, p. 380, t. III, figs. 6a, b.

[2] Frech in Richthofen's *China*, V, (1911), p. 41, t. VI, figs. 1 *a-c*.

[3] Reed, *Palæont. Ind.*, New Ser., Vol. II, Mem. 5, 1908, p. 3, pl. 1, fig. 1.

[4] Mansuy, *Mem. Serv. Géol. Indochine*, Vol. III, fasc. 2, 1914, p. 4, pl. 1, figs. 3 *a-d*.

[5] Gürich, *Verhandl. russ. kais. Miner. Gesell.* Ser. 2, Bd. XXXII, 1896, p. 140, t. V, figs. 7 *a-d*.

variety described by the author from Chitral.[1] The branches are regularly cylindrical, mostly straight or slightly curved, rarely branching, and measure 4-5 mm. in diameter, and on half the circumference they possess 3-5 large deep oblique calices, higher than wide, with strongly curved lower lip.

Striatopora cf. *Tchichatschewi* von Peetz.

There is another larger species of *Striatopora* represented by one branch about 76 mm. in length weathered out on the surface of a piece of limestone and in very fair preservation. This branch which is 8-9 mm. in diameter is cylindrical and nearly straight and shows 5-6 cell-mouths on half the circumference. The corallites which are conical meet the surface obliquely and have circular or even slightly transversely subcircular mouths where the surface is somewhat abraded. This specimen also shows the occasional but rare introduction of rather smaller corallites, but most of the corallites are of regular and uniform size, measuring about 2 mm. in diameter at the mouth. The radial striation of the vestibule is visible in some cases and, where the interior of the corallites is exposed by fracture, large mural pores arranged rather far apart and irregularly, but in one or more linear series, can be detected. This species is undoubtedly comparable, if not identical, with *Str. Tchichatschewi* von Peetz[2] of the Middle Devonian of Siberia, agreeing in the character of the stems and size of the corallites. No sign of branching is observable in our specimen.

The Chitral coral[3] considered to be allied to this Russian species is distinct from the Padaukpin fossil which is more like the coral from the Upper Devonian of Chitral described as *Str. devonica* Schlüt. var. *chitralensis* Reed.[4]

Striatopora cf. *Suessi* Penecke.

Some small fragmentary specimens of a much smaller species of *Striatopora* occur in the collection, but their precise identification is doubtful. One simple straight cylindrical branch with a diameter of 5 mm., tapering slightly to its end, shows 5-6 cell-mouths on half of

[1] Reed, *Palæont. Ind.*, New Ser., Vol. VI, Mem. 2, 1922, p. 21, pl. IV, figs. 10-14.
[2] Von Peetz, *Beitr. Kennt. Fauna devon. Schicht. von Kusnetzk*, (1901. St. Petersburg), p. 379, t. II, fig. 4.
[3] Reed, *Palæont Ind.*, New Ser., Vol. VI, Mem. 2, 1922, p. 22, pl. IV, fig. 15.
[4] *Ibid*, p. 20, pl. IV, figs. 6-9.

the circumference; the corallites meet the surface very obliquely and have large deep vestibules which show in some cases the usual radial striations; the lower lip is deeply concave, and a few large mural pores are visible where the interior of the corallites is exposed.

We may compare *Str. Suessi* Hörn, as described and figured by Penecke [1] from the Devonian of Graz, but *Str. minima* Barrois [2] from the Lower Devonian of Erbray also appears to agree closely in the small size of the branches and the number of corallites.

Alveolites suborbicularis Lamarck.

This widely-spread species is represented in the collection by one large weathered specimen and another showing the corallites in longitudinal section and a portion of the surface of the corallum with the usual laminar expanded form. It ranges from the lowest beds of the Calceola horizon to the lower part of the Upper Devonian, according to Frech,[3] and has been recorded by the author [4] from the Calceola horizon of Padaukpin. A variety of it (*Hudlestoni*) occurs in the Upper Devonian of Chitral.[5]

Alveolites ramosa Roemer.

There is a rather abundant small ramose coral composed of cylindrical rarely dividing mostly straight or slightly flexuous branches 4-8 mm. in diameter which are exposed on weathered surfaces of the rock. Thin sections reveal the characters of *Alveolites ramosa* Roem. such as Frech [6] has described in specimens from the Upper Devonian of Europe. The present author has also described and figured it from Padaukpin [7] and from Chitral,[8] and Mansuy [9] has recorded it from the Upper Devonian of Yunnan.

Aulopora serpens Goldfuss. ?

Some small stolons of an imperfectly preserved species of *Aulopora* are probably referable to the well-known *A. serpens* Goldf. which

[1] Penecke, *Jahrb. geol. Reichsanst.*, XLIII, 1893, p. 608, t. X, figs. 9, 10, t. XI, fig. 12.
[2] Barrois, *Mem. Soc. Géol. Nord.*, III, 1889, p. 36, pl. IV, fig. 2.
[3] Frech, *Zeitsch. deut. Geol. Gesell.* Bd. XXXVII, 1885, p. 108, t. VII, fig. 2.
[4] Reed, *op. cit.* 1908, p. 20, pl. IV, figs. 3, 4, 4*a*.
[5] Reed, *op. cit.* 1922, p. 22, pl. IV, figs. 16-18, pl. V, figs. 1-3.
[6] Frech, *op. cit.* p. 110, t. XI, fig. 8.
[7] Reed, *op. cit.* 1908, p. 21, pl. III, figs. 9-11.
[8] Reed, *op. cit.* 1922, p. 23, pl. V, fig. 4.
[9] Mansuy, *Mem. Serv. Géol. de l'Indo-chine*, Vol. III, fasc. 2, No. 1 (1914) p. 5, pl. 1, figs. 5, 6

has been recorded from many parts of the world in the Middle and Upper Devonian, including Padaukpin.[1]

Favosites vicina sp. nov.

Plate 6, figs. 2, 2*a*.

Corallum massive, discoidal, composed of small densely aggregated long parallel cylindrical corallites of equal or subequal size, hexagonal or polygonal in transverse section, but with circular lumen owing to thickening of the walls near the surface. Tabulae numerous complete, mostly horizontal, situated at rather irregular distances, apart but generally at about twice the diameter of a corallite; pores small, irregularly and sparsely distributed in walls.

Dimensions.

12·15 corallites	to 5 mm.
Diameter of corallum	c. 58 mm.

Remarks.—The small size of the corallites in this species and its general characters indicate that it belongs to the group containing *F. dillensis* Frech,[2] *F. stromatoporoides* Roem.,[3] from the Upper Devonian of Germany, and *F. forojuliensis* Vin. de Regny [4] from the Middle Devonian of Carinthia. We may especially compare the variety *pinnata* [5] of the last mentioned species. The mural pores are represented by small black dots piercing the walls in transverse and longitudinal micro-sections of our specimens and can readily be seen with a hand-lens. But the weathered corallum has a deceptive resemblance to a monticuliporoid.

This group of the genus *Favosites* seems to be specially characteristic of the Upper Devonian, though the Italian species is said to come from the middle division.

Orthis (*Schizophoria*) *striatula* Schlotheim.

This well-known but somewhat variable cosmopolitan Devonian species is represented in the present collection by two fairly perfect specimens of small size, the larger measuring 22 mm. in length,

[1] Reed, *op. cit.* 1908, p. 28, pl. IV, figs. 10, 11.
[2] Frech, *Zeitschr, deut. geol. Gesell.*, Bd. XXXVII, 1885, p. 947, text-figs. 1 and 2.
[3] *Ibid.* p. 950, text-figs. 6 and 7.
[4] Vinassa de Regny, *Palæont. Ital.*, Vol. XXIV, 1918, p. 96, t. VIII, figs. 1-4.
[5] *Ibid.* p. 96, t. VIII, figs. 5, 6.

24 mm. in width and 12 mm. in thickness. There is much difference of opinion about the synonymy of this species, some authors including forms which have been separated off by others as distinct species. The author [1] has referred to this matter on a previous occasion, and Clarke and Swartz[2] have more recently remarked that *O. striatula* is a member of a chain of closely allied shells occurring at various horizons in the Devonian. Hayasaka [3] adopts the unusual custom of referring this species to *Dalmanella*, thus following Quiring's usage, but it is not widely accepted. Our specimens seem to agree closely with the Frasnian shells from Aachen identified by Klähn [4] with *Schizophoria resupinata* Mart. var. *iowaënsis* Hall.

Orthis (*Schizophoria*) *Ivanovi* Tschernyschew.

Plate 7, fig. 6.

There is one nearly complete example of a species of *Schizophoria* which seems to be identical with the shell from the Upper Devonian of the Urals named by Tschernyschew *Orthis Ivanovi*.[5] The characteristic low median fold on the brachial valve can be faintly distinguished in our specimen. Klähn [6] records and figures this species from the Frasnian of Aachen, and Tschernyschew (*op. cit.*) points out its close relations to *Sch. iowaënsis* Hall [7] and *Sch. MacFarlanei* Meek, the latter occurring in the Upper Devonian of south-west China.[8] The variety of *Sch. iowaënsis* termed *magna* by Fenton [9] is much like our shell.

The separation of these forms as species from *O. striatula* is a matter of opinion,[10] and the author is inclined to regard *O. Ivanovi* as only a variety.

[1] Reed, *Palæont. Indica*, New Ser., Vol. II, Mem. 5, 1908, p. 79, pl. XIII, figs. 19-24; *ibid.* Vol. VI, Mem. 2, 1922, p. 34.

[2] Clarke and Swartz, *Maryland Geol. Surv., Mid. and Up. Devonian*, 1913, p. 572, pl. LII, figs. 14-18; pl. LIII, figs. 1, 10.

[3] Hayasaka, *Science Rept. Tohoku Imper. Univ.* Ser. 2 (Geol.), Vol. VI, No. 1, 1922, p. 58, pl. II, figs. 20-22.

[4] Klähn, *Jahrb. preuss. geol. Landesanst.*, XXXIII, 1912, I, p. 7, t. II, figs. 2 *a-e*.

[5] Tschernyschew, *Mem. Com. Geol. St. Petersb.*, Vol. III, No. 3, 1887, pp. 104, 178, t. XII, figs. 3-7.

[6] Klähn, *op. cit.*, 1912, 1, p. 8, t. II, pp. 1, 3, 4.

[7] Hall, *Geol. Surv. Iowa*, I, pt. 2, 1858, p. 488, pl. 2, fig. 4.

[8] Kayser, in Richthofen's *China*, IV, 1883, p. 91, t. XIII, figs. 3, 3 *a-f*.

[9] C. L. and M. A. Fenton, *Contrib Mus. Geol. Univ. Michigan*, Vol. I, 1924, p. 85, pl XIX, figs. 12-18.

[10] Schuchert, *Bull. 87 U. S. Geol. Surv.* 1897, p. 375.

Dimensions.

Length	27 mm.
Width	32 mm.
Thickness	20 mm.

Orthis (*Schizophoria*) cf. *hainensis* Maurer.

Maurer [1] described a transversely oval, gently and unequally biconvex brachiopod from the Devonian of Waldgirmes as *Orthisina ? hainensis*, but it is more probably a species of *Schizophoria*, and a complete specimen from our new Padaukpin locality bears a strong resemblance to it in shape, ribbing and small convexity. It may possibly be only a flattened example of *O. striatula*, some shells of which are considerably compressed, and the brachial valve is only slightly convex. Frech [2] considers that his species *Orthis Goescheni* from the upper part of the Middle Devonian of the Eastern Alps is allied to *O. hainensis*, and the Upper Devonian species *Orthisina planiuscula* Semenow and Möller [3] from the Upper Devonian of central Russia may also be compared. *Schizophoria Derjawini* von Peetz [4] from the Lower Devonian of Siberia is regarded by its founder to be allied to *O. hainensis.*

Dimensions.

Length	20 mm.
Width	28 mm.
Thickness	9 mm.

Orthis (*Dalmanella*) *tioga* Hall.

Plate 8, figs. 3, 3*a*.

One well preserved specimen showing both valves and complete except for one cardinal angle occurs in the collection and exhibits all the main features which Hall and others have described and figured in the American species *O. tioga* Hall [5] from the Upper Devo-

[1] Maurer, *Fauna der Kalk v. Waldgirmes* (Darmstadt, 1885), p. 142, t. V, figs 14-16.

[2] Frech, *Zeitschr. deut. geol. Gesell.*, XLIII, 1891, p. 680, t. XLIV, figs. 2 2c.

[3] Semenow and Moller, *Ober. devon. Schicht. mittl. Russl.* (Melanges phys, et chim., V, 1863), p. 692, t. II, figs. 9 *a-c*.

[4] Von Peetz, *Beitr. Kennt. Fauna devon. Schicht Kusnetzk* (St. Petersburg, 1901), pp. 75, 373, t. IV, figs. 10 *a-c*.

[5] Hall, *Palæont. New York*, Vol. 4, pt. VI, 1867, p. 59, pl. VIII, figs. 20-29; Hall and Clarke, *ibid.* Vol. VIII, Brach. 1, pl. VI, figs. 17, 18.

nian (Chemung Formation) of New York, Maryland,[1] etc. The compressed shape and transversely elliptical outline of the shell, the marked but weak carination of the pedicle-valve, the corresponding median sinus in the brachial valve and the often fasciculate angular raised thin riblets curving upwards on the hinge-line, are well seen in our specimen. This species has previously been recognised outside America in the Upper Devonian of Kusnetzk, Siberia.[2] *O. interlineata* Sow.[3] from the Upper Devonian of England is closely allied,[4] and *O. eifeliensis* Schnur, to a less extent.

Hall and Clarke put *O. tioga* in the subgenus *Schizophoria*, but most American authors now place it in *Dalmanella*.

Dimensions.

Length	20 mm.
Width	27 mm.

Stropheodonta (Douvillina) imitatrix sp. nov.

Plate 7, figs. 1—5.

Shell rounded-subquadrate, nearly as long as broad, gently concavo-convex, compressed, deepest at two thirds its length, slightly geniculated towards anterior margin; hinge-line straight, equal to width of shell, denticulated; cardinal angles slightly projecting, subrectangular, subauriculate. Pedicle-valve gently convex; ears small, short, weakly marked off, more or less subrectangular, slightly projecting at sides; beak small, inconspicuous, with straight, sharp, divergent umbonal edges; hinge-area narrow, triangular, steeply inclined, with coarse transverse denticulate striations. Brachial valve more or less flattened posteriorly and gently concave anteriorly; beak very small, not projecting over cardinal margin; hinge-area narrow, transversely denticulate. Interior of pedicle-valve with short broad transversely triangular muscle-scar, about one-fifth the length of the valve, having a nearly straight anterior edge furnished with a pair of short approximate median points, and the posterior edges sharp and strongly divergent, making a very acute angle with

[1] Clarke and Swartz, *op. cit.*, 1913, p. 569, pl. LII, figs. 1-4.
[2] Von Peetz, *op. cit.*, 1901, p. 74, t. III, figs. 7*a*, *b*.
[3] Davidson, *Mon. Brit. Foss. Brach.*, III, pt. 6, p. 91, pl. XVII, figs. 18-23.
[4] Asselberghs, *Bull. Soc. Géol. France*, Ser. 4, XXVI, 1926, p. 69.

the hinge-line; muscle-scar composed of a pair of short broad triangular divergent diductors abruptly truncated in front and embracing a pair of small oval deeply impressed adductors separated by a narrow median ridge. Interior of pedicle-valve coarsely papillose in middle, but with the papillae becoming suddenly smaller and closer together towards the edges of the valve, so as to form a broad indefinite band round the margins and along the hinge-line. Interior of brachial valve with feebly marked muscle-scars and pair of slightly divergent straight vascular ridges; papillation of surface as in other valve. Cardinal process stout, bifurcate, with broad lobes.

Surface of valves ornamented with 40-50 radial equidistant or subequidistant thread-like lines of which most are primaries, with wide interspaces between them, each holding 6-10 fine radial striae.

Dimensions.

Length	26-29 mm.
Width	29-31 mm.

Remarks.—This shell must be referred to the subgenus or genus *Douvillina*, but it is distinct from the shell from the Upper Devonian of Chitral named by the author *Stroph.* (*Douv.*) *Dutertrii* De Vern. var. *asiatica* [1] and it more resembles *Douvillina ferquensis* Rigaux [2] from the Upper Devonian of Ferques, though our species is more quadrate in form. It also seems to resemble *D. interstrialis* Schmidt [3] (non *Str. interstrialis* Phill.) from the Cultrijugatus zone of Germany, but the internal characters are distinctive. It is unfortunate that several different forms, all referable to the genus *Stropheodonta* or to one of its subgenera have received the specific name *interstrialis*, and in consequence of this there has been some confusion. *Stroph. interstrialis* Vanuxem [4] which is now put in the subgenus *Leptostrophia* must not be confused with Schmidt's *Stroph.* (*Douvillina*) *interstrialis* nor with Phillips' *Str. interstrialis* of which the variety

[1] Reed, *Palæont. Indica*, New Ser., Vol. VI, Mem. 2, 1922, p. 36, pl. VI, figs. 16, 17, pl. VII, figs. 1, 1*a*, *b*.

[2] Rigaux, *Mem. Soc. Acad. Boulogne*, Vol. V, 1872, pl. 1, fig. 8; *id.*, *Le Devonien de Ferques et ses Brachiopodes* (Boulogne, 1908), p. 29.

[3] Schmidt, *Jahrb. preuss. geol. Landesanst.*, XXXIII, 1912, 2, p. 314, t. XXIII, figs. 9*a*, *b*.

[4] Clarke and Swartz, *op. cit.*, 1913, p. 554, pl. XLVIII, fig. 7.

birmanica [1] has been described in detail from the Calceola bed at Padaukpin. Mansuy [2] unfortunately described a form from Yunnan as *Douvillina interstrialis*, Phill., but it is neither identical with the variety *birmanica* nor with our new species.

None of the Upper Devonian species of *Douvillina* from America can be considered as closely allied, though *Str.* (*D.*) *arcuata* Hall [3] and *Str.* (*D.*) *cayuta* Hall [4] show many points of resemblance; the surface ornamentation is, however, different.

The species from the Upper Devonian of Iowa named by the Fentons *D. delicata* [5] appears to have the shape and sub-marginal geniculation of our shell, but the ornamentation is distinct for, as above noted, ours possesses that of *Stroph. interstrialis* Phill.

Clarke and Swartz (*op. cit.*) and Fenton (*op. cit.*) follow Rigaux and Mansuy in raising *Douvillina* to generic rank. But Spriesterbach [6] regards it as a subgenus of *Stropheodonta*. Schuchert [7] in 1897 in his Synopsis of American Fossil Brachiopoda did not recognise it, and put *Str. arcuata* in *Stropheodonta*.

We may draw attention to the remarkable external resemblance of the British shell figured by Davidson from the Wenlock Beds as *Strophomena imbrex* Pander var. *semiglobosa* Dav.[8], the shape and ornamentation of the surface closely corresponding with our Padaukpin species. But it does not seem probable that they are genetically connected, and a homœomorphic relation is suggested.

Orthothetes (*Schellwienella*) *umbraculum* (Schlotheim).

This old-established European species which typically occurs in the Middle Devonian was found to occur in considerable abundance at this new locality. Most of the specimens are of large size and have weathered out completely from the matrix. The specimens are of the transverse variety with acutely pointed cardinal

[1] Reed, *Palæont. Indica*, New Ser., Vol. II, Mem. 5, 1908, p. 66, pl. X, figs. 11-13, pl XI, figs. 1-6.
[2] Mansuy, *Mem. Serv. Géol. Indo-chine*, Vol. I, fasc. 2, 1912, p. 72, pl. XIII, figs. 4 *a-c*.
[3] Clarke and Swartz, *op. cit.*, p. 555, pl. 48, figs. 8-17, pl. 49, figs. 1, 2.
[4] *Ibid.*, p. 557, pl. XLIX, figs. 14-17.
[5] C. L. and M. A. Fenton, Stratigraphy and Fauna of the Hackberry stage of the Upper Devonian, Iowa (*Contrib. Mus. Geol. Univ. Michigan*, Vol. 1, 1924), p. 91, pl. XX, figs. 17-20.
[6] Spriesterbach, *Jahrb. preuss. geol. Landesanst.*, XLV, 1924, p. 432.
[7] Schuchert, *Bull. 87, U. S. Geol. Surv.*, p. 419.
[8] Davidson, *Mon. Brit. Foss. Brach.*, Vol. III, p. 286, pl. XLI, figs. 1-6.

angles like the form figured by Davidson[1] from Hope's Nose, Torquay.

Since the author[2] figured a large series of examples from the Calceola horizon at Padaukpin several other authors have recorded the species from elsewhere and discussed its characters, and Quiring[3] has given a useful list of references to the recent literature. Paeckelmann[4] records it from the Upper Devonian of the Rhine, and Mansuy[5] from the Black River region of Tonkin. There is a great similarity (as the author (*op. cit.*) has pointed out) in the character of the cardinal process, etc., of this species and of *O. chemungensis* (Conr.) which Clarke and Swartz[6] put in the genus *Schuchertella*, but Thomas[7] and Paeckelmann refer *O. umbraculum* to *Schellwienella* as did the author in 1908.

Atrypa reticularis Linn. var. nov. *subauriculata*.

Plate 7, fig. 8; Plate 8, figs. 1, 2, 2*a*, 2*b*.

The habit of most of the representatives of this species occurring at this new locality is rather peculiar and corresponds closely to that of the form from Ferques which Rigaux[8] separated off as a distinct species under the name *Legayi*, and one of the specimens of *A. reticularis* figured by Wenjukoff[9] from the Devonian of Kolpna on the river Sosna, in Russia, seems to be identical with our variety.

The brachial valve is deep and strongly swollen in the middle, tending to form a rounded indefinite median fold anteriorly and thus to cause a strong sinuation of the anterior margin. The pedicle-valve is very shallow and becomes flattened or slightly concave anteriorly, but is gently convex near the beak; a shallow indefinite median rounded sinus tends to be formed near the anterior margin of this valve which is more or less produced into a short rounded tongue The cardinal angles of both valves are subrectangular or abruptly rounded and are usually rather flattened and sub-

[1] Davidson, Mon. Brit. Foss. Brach., Vol. V, Suppl. pl. III, fig. 20.

[2] Reed, *Palæont. Indica*, New Ser., Vol. II, Mem. 5, 1908, p. 75, pl. XIII, figs. 2 14.

[3] Quiring, *Neues Jahrb. f. Miner. Geol.* I, 1914, p. 123.

[4] Paeckelmann, *Abhandl. preuss. geol. Landesanst.*, N. F. Heft 70, 1913, p. 317.

[5] Mansuy, *Mem. Serv. Géol. Indo chine*, Vol. VIII, fasc 1, 1921, p. 44, pl. III, fig. 23.

[6] Clarke and Swartz; *Maryland Geol. Surv. Mid. and Up. Devon.*, 1913, p. 559.

[7] Thomas, *Mem. Geol. Surv. Gt. Brit.*, Palæont., Vol. 1, pt. 2, 1910, p. 107.

[8] Rigaux, *Le Devonien de Ferques* (Boulogne, 1908), p. 22, pl. 2, figs. 10 *a-c*.

[9] Wenjukoff, *Fauna Devon. Syst. nordwest, u. centr. Russl.* (St. Petersb., 1886), p. 514, t. VI, fig. 5 (*non cet.*).

auriculate, so as to give a somewhat subtriangular outline to the shell, the hinge-line being nearly straight, but the beak of the pedicle-valve is closely incurved, and there is no hinge area. The ornamentation of the surface is rather coarse, the ribs being less numerous than in the typical *A. reticularis*, and the concentric lamellae are few.

In the somewhat extended straighter hinge-line, flattened cardinal angles and their subauriculate appearance our form more resembles the variety from the Devonian of China named by Hayasaka [1] *auriculata*, of which a probable but imperfect specimen was described by the author from Yunnan,[2] and in its general shape and characters it seems identical with one specimen of *A. reticularis* previously figured from Padaukpin.[3]

In Iowa a form from the Upper Devonian which much resembles our variety in shape, but has finer and more numerous ribs, has been separated as *A. devoniana* Webster,[4] and its variety *alta* [5] has a swollen brachial valve as in our form.

Our Padaukpin shell appears to be sufficiently distinct from all the foregoing to warrant a definite name, though it can only be regarded as a variety of *A. reticularis*, and from its resemblance to the Chinese *auriculata* it may be termed *subauriculata*.

The brachial spires are well exposed by weathering in two of our specimens and show 16-18 coils, but no peculiar internal features are visible by which one can distinguish them from adult Wenlock examples of the species such as Davidson [6] figured.

Dimensions.

Length	38-50 mm.
Width	42-50 mm.
Thickness	21-25 mm.

There are some much smaller specimens in the collection up to 30 mm. in length which have the nearly straight hinge-line and subquadrate cardinal angles of the above-named variety, the shell being widest along the hinge-line, but the valves are of nearly

[1] Hayasaka, *Science Rept. Tohoku Imper. Univ.* Ser. 2 (Geol.), Vol. VI, No 1, 1922, p. 47, pl. II, figs. 2, 3.

[2] Reed, *Palæont. Ind.*, New Ser., Vol. X, Mem. 1, 1927, p. 15, pl. II, fig. 8.

[3] Reed, *ibid*, 1908, pl. XV, fig. 5 (*non cet.*).

[4] Fenton, *op. cit.*, 1924, p. 136, pl. XXVI, figs. 16-24.

[5] *Ibid.*, pl. XXVI, figs. 25, 26.

[6] Davidson, *Mon. Brit. Foss. Brach*, Vol. V, Suppl., p. 109, pl. VI, figs. 14, 15, pl. VII, figs. 1-6.

circular shape, are devoid of fold or sinus, being regularly biconvex, but the pedicle-valve is always less convex than the brachial. Probably these represent young individuals, but the radial ribs are rather smaller and more numerous than in the supposed adult form above-described, though this is often only an individual variation. Mansuy [1] has figured similar examples of *A. reticularis* from the Devonian of Tonkin.

The species *A. reticularis* as represented in the Middle Devonian has been generally recognised to comprise several varieties,[2] apart from the possible inclusion of *A. desquamata* within its limits. But the question of the specific separation of the many forms of *Atrypa* occurring in the Devonian is still debateable. Gürich [3] and the author [4] were inclined to put nearly all in the one species *A. reticularis*, but Torley,[5] Paeckelmann,[6] Rigaux (*op. cit.*) and recently Leidhold[7] as well as some American authors recognise several species.

Atrypa Douvillei Mansuy, var.

Plate 7, fig. 7.

This species which was founded by Mansuy [8] on specimens from the Upper Devonian of Ta-hi-ti, Yunnan, is closely related to *A. desquamata* Sowerby, a species variously interpreted,[9] and especially to *A. aspera* var. *sinensis* Kayser,[10] being intermediate between them as Mansuy [11] has pointed out. From the latter Mansuy's species differs chiefly by its subcircular instead of suboval form and more numerous ribs, and it seems sufficiently distinct to rank as specifically independent. From the former it differs by its less numerous, coarser ribs and subequal convexity of the valves. One small biconvex subcircular shell in our collection appears to be referable to it, as it possesses the shape and rather elevated beak

[1] Mansuy, *Contrib. Carte géol. Indo-chine, Palæont.* (*Service de Mines*, 1908), p. 43, pl. XI, figs. 6-13.

[2] Gortani, *Palæont. Ital.*, Vol. XVII, 1911, p. 157.

[3] Gürich, *Verh. russ. K. Miner. Gesell.*, Ser. 2, Bd. XXXII, 1896, pp. 270-272.

[4] Reed, *op. cit.*, 1908, pp. 96, 97.

[5] Torley, *Abh. preuss. geol. Landesanst.* N. F. Heft 53, 1908, p. 23.

[6] Paeckelmann, *op. cit.*, 1913, pp. 279-284.

[7] Leidhold, *Abh. preuss. geol. Landesanst.* N. F. Hept 109, 1918, pp. 91-98.

[8] Mansuy, *Mém. Serv. Géol. Indo-chine*, Vol. I, fasc. 2, 1912, p. 74, pl. XIII, fig. 9 *a-h.*

[9] Reed, *Palæont. Ind.*, New Ser., Vol. X, Mem. 1, 1927, pp. 15, 16 and references; Hayasaka, *op. cit.*, 1922, p. 44, pl. 1, figs. 12-15. Leidhold, *op. cit*, 1928, p. 96.

[10] Kayser in Richthofen's *China*, IV, 1883, p. 83, t. IX, figs. 3, 3 *a-g.*

[11] Mansuy, *op. cit.*, 1912, p. 74, pl. XIV, figs. 2 *a-c.*

of the pedicle-valve but the ribbing is rather less coarse than Mansuy describes and thus more approaches *A. desquamata.* The brachial valve of our specimen has been worn away almost completely so as to expose one of the brachial spires.

Dimensions.

Length and width	19 mm

Spirorbis omphalodes Goldfuss.

Two examples of this annelid occur in the collection attached to shells of *Stroph.* (*Douvillina*) *imitatrix.* It has previously been recorded from Padaukpin [1] and from various other parts of Asia as well as Europe.

CORRELATION.

With regard to the correlation of this fauna it appears that its affinities are rather with the lower part of the Upper Devonian than with the Middle Devonian. The genera *Phillipsastræa* and *Douvillina* are typically Upper Devonian; *Orthis Ivanovi* and *Orthis tioga* likewise belong to this division of the formation, and the variety of *Atrypa reticularis* and of *A. Douvillei* are also closely similar to shells from beds of this age. The species of *Endophyllum, Striatopora* and *Alveolites* point the same way. A few species, such as *Orthis striatula, Orthothetes umbraculum* and *Alveolites suborbicularis* occur in both the Middle and Upper Devonian. There is no characteristic Middle Devonian fossil such as *Calceola sandalina* present, and the fauna thereby of the previously described Padaukpin locality with its abundant examples of this coral is markedly different. The whole facies is also distinct, and the abundance of massive corals is a special feature.

The evidence therefore as far as it goes indicates that we have to deal with an early fauna of Upper Devonian age.

In the neighbouring province of Yunnan Mansuy [2] has described a considerable fauna of Upper Devonian age, and beds of this age also occur in Indo-China.

[1] Reed, *op. cit.*, 1908, p. 43, pl. VI, fig. 13.
[2] Mansuy, *op. cit.*, 1912, pp. 71-83.

II. NEW FOSSILS FROM THE ZEBINGYI BEDS, BURMA.

Locality 1.

During the author's visit to Burma and the Shan States in 1927 a small collection of fossils was made from the Zebingyi Beds on the Mandalay-Maymyo road where the rocks are occasionally exposed in the cuttings. These exposures were not available when Mr. T. D. LaTouche examined the beds in 1900 and subsequent years, and as some new species have been obtained it is desirable to place them on record.

Near mile-post "31" on this road pink, white and yellow soft shales yielded abundantly *Tentaculites elegans* and *Styliolina laevis*, with occasional examples of *Phacops* aff. *shanensis* and crinoid stem joints. A small brachiopod which may be regarded as a variety of *Stropheodonta comitans* Barr. is described below, and is new to this locality. A small ostracod, perhaps referable to the genus *Aristozoe*, also occurs at this locality, and a doubtful specimen of *Orthonychia* was collected.

At mile-post "32-7" on the same road some pygidia and fragments of *Phacops* aff. *shanensis* (but no head-shields) were obtained from similar beds which also yielded a few examples of the variety of *Stropheodonta comitans* Barr. A small badly preserved meristoid shell of rather doubtful generic reference and a pentameroid allied to *Pentamerus Krasnopolskii* Tschern. were also found. It was remarkable that graptolites were practically absent, only one fragment of a *Monograptus* being obtained in the course of a detailed search in the various sections along this road.

The full description of the fauna of the Zebingyi Beds in this area was given by the author in 1906 [1] with a few further remarks in 1915,[2] while in 1913 Mr. T. D. LaTouche [3] described the stratigraphical relations and occurrence of this interesting formation.

The following are the new fossils collected along this road :

Stropheodonta comitans Barr. var. nov. *subimbricata.*

Meristella cf. *recta* Barrois.

Pentamerus (*Clorinda*) aff. *Krasnopolskii* Tschern.

[1] Reed, *Palæont. Indica*, New Ser., Vol. II, Mem. 3, 1906, pp. 90-154.
[2] *Ibid*, Vol. VI, Mem. 1, 1915, pp. 89, 98.
[3] LaTouche. *Mem Geol Surv. India*, Vol. XXXIX, pt. 2, 1913, pp. 163-181.

Stropheodonta comitans (Barrande) var. nov. *subimbricata.*

Plate 8, figs. 4, 4*a*, 5.

Shell transversely subsemicircular to semiquadrate, cardinal angles rectangular; hinge-line straight, equal to width of shell; valves closely appressed. Pedicle-valve gently convex, most so in the middle posteriorly, with weak broad median depression, but slightly flattened towards the cardinal angles; hinge-area low, narrow, triangular; beak small, slightly incurved and scarcely projecting behind; interior of valve with pair of very small short suboval muscle-scars strongly diverging outwards at 80°-90°, and with a minute papillation over the whole surface. Brachial valve gently concave, most so posteriorly; beak inconspicuous; hinge-area linear, very narrow; hinge-line with minute denticulations. Surface of valves marked with 10-16 straight, fine, thread-like radial ribs, mostly primaries, equidistant and of equal strength, separated by wide flat interspaces marked with much finer radial striae; 8-10 regular equidistant thin lamellose concentric ridges, usually stronger on the pedicle-valve than on brachial valve, cross the whole surface.

Dimensions.

Length	2·5-4·0 mm.
Width	5·25-6·0 mm

Localities.—Near mile-posts "31" and "32-7" on the road from Mandalay to Maymyo.

Remarks.—This small brachiopod much resembles certain Bohemian shells named *Strophomena comitans* Barr.[1] from Stage Gg 2 which have a similar concentric ornamentation and radial lineation, but the Silurian examples of this species figured by Barrande from Stage E. and those from Stage F. are less subquadrate, lack the regular concentric ridges of our form and have more pointed cardinal angles. Tschernyschew [2] has figured and described the species *Str. comitans* from the Lower Devonian of the Western Urals, and recently Kegel [3] has recorded it from the "Steinberger Kalk" near Giessen and points out its resemblance to or identity with *Stroph. minor* Roem. as described by Walther.[4]

[1] Barrande, *Syst. Silur. Bohême,* Vol. V, 1879, pl. 56, figs. 18-23 (*non cet.*).
[2] Tschernyschew, *Mem. Com. Geol. St. Petersb.,* III, 1, 1885, p. 59, t. VII, figs. 98, 99.
[3] Kegel, *Abh. preuss. geol. Landesanst,* N. F. Heft 100, 1926, p. 31.
[4] Walther, *Neues Jahrb. f. Miner.Geol.* Beil., Bd. XXIV, 1907, p. 283, t. XIII, fig. 14 a-*f*.

Meristella cf. *recta* Barrois.

There are some crushed specimens of a small broadly oval Meristoid shell from the Zebingyi Beds in a poor state of preservation, but the internal casts show some of the internal characters and external impressions have the surface ornamentation preserved. It does not seem to be identical with the poor specimen from Zebingyi (2) described and figured by the author in 1906 as *Meristina* ? sp.,[1] for the latter is transversely oval in shape, while nothing is known of its internal characters. Our present specimens seem to have the shape and characters of *Meristella recta* Barrois [2] which is nearly identical with some of Barrande's *M. circe*, and they show the internal median septum in the brachial valve, while there is usually an absence of any distinct fold or sinus on the surface of the valves. The usual fine concentric growth-lines are visible in the impressions of the valves. But whether this shell should be referred to *Merista* rather than to *Meristella* is doubtful, and one specimen which shows a weak median sinus on the pedicle-valve has more the aspect of *Merista passer* Barr. which has been recorded from many localities in Hercynian beds.[3]

Dimensions.

Length	c. 8·0 mm.
Width	c. 7·0 mm.

Locality.—Near mile-post "32-7" on the road from Mandalay to Maymyo.

Pentamerus (*Clorinda*) aff. *Krasnopolskii* Tschernyschew.

There is one external impression of a transversely subelliptical subglobose valve of a brachiopod with a weak rounded median sinus; the cardinal angles are rounded and the beak seems to be rather swollen and strongly incurved. The internal cast of the same valve shows a short triangular spondylium, but the appearance in the specimen of an internal submarginal thickening or ridge near one lateral margin of the valve seems due to an injury and to crushing. Traces of fine, closely placed, irregular, radial vascular markings are visible near the anterior edge of the valve, but both cast and impression are poor. We must undoubtedly refer this shell to some pentameroid, and it may be assigned to the subgenus *Clorinda* [=*Barrandella*], while the

[1] Reed, *Palæont. Ind.*, New Ser., Vol. II, Mem. No. 3, 1906, p. 112, pl. VI, fig. 30.
[2] Scupin, *Zeitschr. deut. geol. Gesell.*, LVIII, 1906, p. 281, t. XVI, fig. 7.
[3] Kegel, *op. cit.*, p. 44.

Hercynian form[1] commonly identified with the British Silurian species *Pentamerus linguifer* (Sow.)[2] may be compared, but it may be suspected that the species is distinct, and our specimen seems more allied to *P. Krasnopolskii* Tschern.[3] of the Lower Devonian of the Urals.

Dimensions.

Length	5·0 mm.
Width	8·5 mm.

Locality.—Near mile-post "32-7" on the road from Mandalay to Maymyo.

Locality 2.

In the course of the same trip through the Northern Shan States a new locality for fossils in these beds was discovered by the author far to the North on the road from Lashio to Mongpyen. Here at mile-post "17-4" dark purplish fissile earthy shales occur in the bank by the road-side with interbedded layers of reddish ironstone and grey tough horny limestone, all gently folded. The shales yielded a few poorly preserved specimens including the following species, none of which has been previously recorded from the Zebingyi Beds, but the general close affinities or identity of the species with well-known Lower Devonian forms occurring elsewhere render the stratigraphical reference of the beds a matter of no uncertainty.

Cypricardinia semisquamosa sp. nov.
Avicula aff. *insidiosa* Barr.
Platyceras sp.
Entomis pelagica Barr.
Entomis cf. *phalanga* Kegel.

No trace of graptolites or *Tentaculites* was observed in the beds at this locality, and it is probable that the horizon is rather higher than those near Zebingyi yielding such fossils.

Cypricardinia semisquamosa sp. nov.

Plate 8, figs. 7, 7*a*.

Shell transversely oblong, slightly oblique, widening to the posterior end. Body gently convex; beak small, rounded, situated near

[1] Kegel, *op. cit.*, p. 38, t. III, figs. 10*a*, *b*, 11*a-c*
[2] Davidson, *Mon. Brit. Foss. Brach.*, III (Palæont. Soc.), p. 149, pl. XVII, figs. 11-14.
[3] Tschernyschew, *Mem. Com. Géol St. Petersburg*, Vol. IV, No. 3, 1893, pp. 78, 180, t. XIII, figs. 1-4.

the anterior end which is sharply rounded ; cardinal margin straight, horizontal; rather less than the length of the shell ; posterior end of body sharply rounded below, obliquely truncate above with nearly straight margin meeting cardinal edge at an obtuse angle ; posterior wing somewhat flattened and depressed, elongated triangular, weakly marked off from body.

Surface of shell marked with regular, equidistant, concentric, overlapping lamellae, 4 or 5 of which are specially thickened and elevated on the anterior slope of the body in the umbonal region.

Dimensions.

Length	c. 7 mm.
Height at posterior end	c. 5 mm.

Locality.—Near mile-post "17-4" on the road from Lashio to Mongpyen.

Remarks.—There is only one fairly well-preserved impression of the exterior of this shell with its internal cast, though several fragments of other specimens occur in the collection. It is undoubtedly closely allied to *C. nitidula* Barrande [1] from Stage Ff 2 and to its variety *contexta*, but *C. squamosa* Barr., which Kegel [2] has recently figured from the Lower Devonian of the Giessen area, resembles it in the prominence of its concentric lamellae, though in the European form they are equally prominent over the whole shell. Hermann [3] considers *C. nitidula* to be inseparable from *C. crenistria* Sandb. [4] of the Upper Coblenzian, and he would also put *C. crenicostata* Barrois [5] in the same species. Chapman [6] has figured *C. conterta* Barr. from the Yeringian (Silurian) of Victoria, Australia.

But there is a large number of closely allied species, such as *C. scalaris* Phill.[7] of the Middle Devonian, *C. planulata* Conr.[8] of the Schoharie Grit, *C. distincta* Billings [9] of the Grande Grève Limestone,

[1] Barrande, *Syst. Silur. Bohême*, Vol. VI, pt. 1, pl. 257, fig. .

[2] Kegel, *Abh. preuss. geol. Landesanst.* N. F. Heft 100, 1926, p. 29, t. II, figs. 7 *a*, *b*.

[3] Hermann, *Jahrb. preuss. geol. Landesanst.*, XXXIII, I, 1912, p. 336.

[4] Beushausen, *Abh. preuss. Geol. Landesanst.* N. F. Heft 17, 1895, p. 178, t. XVI, figs. 9-13.

[5] Barrois, Faune d'Erbray (*Mem. Soc. Géol. Nord.*, Vol. 3, 1889), p. 167, pl. XI, fig 9. Gortani, *Palæont. Italica*, Vol. XVII, 1911, p. 200, t. XIX, fig. 23.

[6] Chapman, *Mem. Nat. Mus. Melbourne*, No. 2, 1908, p. 53, pl. VI, figs. 82-84.

[7] Whidborne, Mon. Dev. Fauna (*Palæont. Soc.*) Vol. II, pt. 1, 1891, p. 5 and pl. I, figs. 6-8 ; Gortani, *op. cit.*, 1911, p. 197, t. XIX, fig. 22.

[8] Hall, *Palæont. New York*, Vol. V, pt. 2, 1885, p. 484, pl. 89, figs. 1-5.

[9] Clarke, *Mem. 9, New York State Mus.* pt. 1, 1908, p. 157, pl. 24, figs. 17-19.

C. indenta Conr.[1] of the Hamilton beds and *C. arcuata* Hall[2] of the Chemung. Dahmer[3] has described an Upper Coblenzian species as *C. richteri* which recalls *C. scalaris*. But with none of these species can our Lashio form be considered identical on account of the peculiar limitation of its strong concentric lamellae to the anterior portion of the valves.

Avicula aff. *insidiosa* ? Barrande.

Plate 8, figs. 6, 6*a*.

The external impression and internal cast of the two valves of one small lamellibranch about 3·75 mm. in length lie side by side in natural position on a fragment of the shale, but unfortunately they are not quite perfect. The shell is much laterally compressed, the valves being very shallow; in shape it is subquadrate; the cardinal margin is straight, but not as long as the shell, the posterior cardinal angle being obtuse. A weakly defined triangular posterior wing is present. The posterior end of the shell is obliquely truncate in its upper half forming the edge of the posterior wing, but the lower angle is broadly rounded; the inferior margin is also broadly rounded and passes up into the convex anterior end; the beaks are terminal, obtuse, low and broad, with a small anterior ear projecting below them, but this part is poorly preserved. In the internal cast there is a long narrow thickened, ligamental area extending the whole length of the cardinal margin, and below it a slightly shorter oblique lateral tooth making a very acute angle with it. Below the beaks are traces of 2-3 small transverse teeth on a small broad thickened hinge-plate. The surface is marked with fine concentric growth-striae.

The generic reference and affinities of this specimen have been a matter of some difficulty owing to its poor state of preservation, but it seems to resemble the Bohemian shell termed by Barrande *Avicula insidiosa*[4] from stages G and H, in which species there is a considerable variation in the shape, but some of the figured specimens are much like our shell. *A. impatiens* Barr.[5] from stage E seems less closely allied. The generic reference is doubtful.

Locality.—Near mile-post "17-4" on the road from Lashio to Mongpyen.

[1] Hall, *op. cit.*, p. 485, pl. 89, figs. 6-16, 23.
[2] Hall, *op. cit.*, p. 486, pl. 89, fig. 17.
[3] Dahmer, *Jahrb. preuss. geol. Landesanst.*, XXXVI, 1, 1916, p. 272, t. VIII, figs. 17-19
[4] Barrande, *Syst. Silur. Bohême*, Vol. VI, 1881, p. 24, pl. 230, figs. III, 1-26.
[5] *Ibid.*, pl. 245, fig. IV.

Platyceras sp.

A minute species of *Platyceras* is represented by an internal cast and broken impression of the exterior on the same slab as some ostracods. It appears to resemble the Bohemian species *Pl. hamulus* Barr. [1] which is also figured by Hermann [2] (*non* Spitz [3]) from the Lower Devonian of Germany.

Locality.—Near mile-post " 17-4 " on the road from Lashio to Mongpyen.

Entomis pelagica Barrande.

There is one good example of this species in a soft purple shale occurring at mile-post " 17-4 " on the road from Lashio to Mongpyen, and it is associated with some other small ostracods.

Entomis pelagica Barr.,[4] which is considered by some authors as identical with *E. tuberosa* Jones.,[5] has been recorded not only from Bohemia, but also by Tschernyschew [6] from the Lower Devonian of the Urals, by Gortani [7] from the Capolago district in the Carnic Alps and by Paeckelmann[8] from the Bosphorus, but in all cases from Lower Devonian beds of the Bohemian facies; Barrande described it originally from Stage Ff 2.

Locality.—Near mile-post " 17-4 " on the road from Lashio to Mongpyen.

Entomis cf. *phalanga*, Kegel.

One small subelliptical valve of another species of *Entomis* occurs in the collection and is very closely similar to *E. phalanga* Kegel[9] from the Lower Devonian of Giessen, the only apparent difference being in the valve which is rather less inflated. The surface is similarly smooth and is crossed by the typical, gently curved, transverse furrow reaching about half-way across the valve. Only the impression of a right valve is known measuring about 1 mm. in length and about 0·75 mm. in width. Kegel (*op. cit.*) remarks on the absence of tubercles or swellings on this species which distinguishes it from several allied forms of the Lower Devonian.

Locality.—Near mile-post " 17-4 " on the road from Lashio to Mongpyen.

[1] Perner, *Syst. Silur. Bohême*, Vol. IV, 1, 1903, pl. 32, figs. 21-25.

[2] Hermann, *op. cit.*, 1912, p. 377, t. XXIII, fig. 11.

[3] Spitz, *Beitr. Palæont. Geol. Osterr. Ung. u. d. Orients*, XX, 1907, Heft 3, p. 161, t. XV, figs. 26, 27.

[4] Barrande, *Syst. Silur. Bohême*, Vol. 1, Suppl., 1872, p. 515, pl. 24, figs. 1-0.

[5] Jones, *Mem. Geol. Surv. Scotland*, Explan. Map 32, 1861, p. 137, pl. II, fig. 5.

[6] Tschernyschew *Mem. Com. Geol. St. Petersburg*, Vol. III, 1, 1885, p. 8, t. I, figs. 6*a*, *b* (non. *Ibid.*, Vol. IV, 3, 1893, p. 17, t. I, figs. 12, 13).

[7] Gortani, *Palæont. Italica*, Vol. XXI, 1915, p. 164, t. XV (III), figs. 17, 18.

[8] Paeckelmann, *Abh. preuss. geol. Landesanst.* N. F. Heft. 98, 1925, p. 106, t. v, fig. 2.

[9] Kegel, *op. cit.*, 1926, p. 6, t. I, figs. 1 *a-d.*

PLATE 5.

FIG. 1.—*Phillipsastræa orientalis* sp. nov. (Stanley Smith). Portion of weathered surface of a large corallum. Nat. size. Upper Devonian. Near Padaukpin.

FIG. 2.—Ditto. Portion of weathered surface of another specimen. ×2. Same horizon and locality.

FIG. 3.—Ditto. Tangential section. ×3. Same horizon and locality.

FIG. 3a.—Ditto. Longitudinal section of part of the same corallum. × 3.

PLATE 6.

FIG. 1.—*Phillipsastræa padaukpinensis* sp. nov.; complete corallum. Nat. size. Upper Devonian. Near Padaukpin.

FIG. 1a.—Ditto. Portion of the same specimen. ×2.

FIG. 2.—*Favosites vicina* sp. nov.; tangential section. × 4½. Same horizon and locality.

FIG. 2a.—Ditto. Longitudinal section of the same specimen. ×4½.

PLATE 7.

FIG. 1.—*Stropheodonta (Douvillina) imitatrix* sp. nov. Pedicle-valve of complete specimen. ×2. Upper Devonian. Near Padaukpin.

FIG. 1a.—Ditto. Brachial valve of the same specimen. ×2.

FIG. 2.—Ditto. Portion of pedicle-valve with shell abraded, showing muscle-scars, etc. ×2. Same horizon and locality.

FIG. 2a.—Ditto. Posterior view of cardinal region of both valves of the same specimen. ×2.

FIG. 3.—Ditto. Posterior part of abraded brachial valve, showing muscle-scars. ×2. Same horizon and locality.

FIG. 4.—Ditto. Complete young individual. Nat. size. Same horizon and locality.

FIG. 4a.—Ditto. Median section of the same specimen. Nat. size.

FIG. 5.—Ditto. Portion of the surface of a pedicle-valve. ×4. Same horizon and locality.

FIG. 6.—*Orthis (Schizophoria) Ivanovi* Tschern. Anterior view of complete individual. Nat. size. Same horizon and locality.

FIG. 7.—*Atrypa Douvillei* Mansuy, var. Pedicle-valve of complete individual. ×2. Same horizon and locality.

FIG 8.—*Atrypa reticularis* Linn. var. nov. *subauriculata*. Brachial valve of complete individual. Nat. size. Same horizon and locality.

PLATE 8.

FIG. 1.—*Atrypa reticularis* Linn. var. nov. *subauriculata*. Pedicle-valve of complete individual. Nat. size. Upper Devonian. Near Padaukpin.

FIG. 2.—Ditto. Pedicle-valve of another complete individual. Nat. size. Same horizon and locality.

FIG. 2a.—Ditto. Brachial valve of the same specimen. Nat. size.

FIG. 2b.—Ditto. Posterior view of the same specimen. Nat. size.

FIG. 3.—*Orthis* (*Dalmanella*) *tioga* Hall. Pedicle-valve of complete individual. ×2½. Same horizon and locality.

FIG. 3*a*.—Ditto. Brachial valve of the same specimen. ×2½.

FIG. 4.—*Stropheodonta comitans* (Barrande) var. nov. *subimbricata*. Impression of pedicle-valve. ×5. Zebingyi Beds. Mile-post "32-7" on the Mandalay-Maymyo road.

FIG. 4*a*.—Ditto. Internal cast of the same specimen. ×5.

FIG. 5.—Ditto. Impression of brachial valve. ×5. Zebingyi Beds. Mile-post "31" on the Mandalay-Maymyo road.

FIG. 6.—*Avicula* ? aff. *insidiosa* Barrande. Impression of the exterior of both valves. ×4. Zebingyi Beds. Mile-post "17-4" on the Lashio-Mongpyen road.

FIG. 6*a*.—Ditto. Internal cast of the same specimens. ×4.

FIG. 7.—*Cypricardinia semisquamosa* sp. nov. Impression of the exterior of the right valve ×4. Zebingyi Beds. Mile-post "17-4" on the Lashio-Mongpyen road.

FIG. 7*a*.—Ditto. Internal cast of left valve. ×4. Same horizon and locality.

THE RANGOON EARTHQUAKES OF SEPTEMBER AND DECEMBER 1927. BY J. COGGIN BROWN, O.B.E., D.SC., *Superintendent, Geological Survey of India.* (With Plate 9.)

Introduction.

THREE smart earthquake shocks were experienced in Rangoon on the 10th September 1927 at 12-5 p.m., 12-47 p.m. and 4-25 p.m. (Rangoon Time), but none of them did any appreciable damage. In the early morning of December the 17th, a much severer shock occurred which caused wide-spread alarm and a certain amount of damage, to be described in a later paragraph.

These earthquakes were not like the shocks of May, 1912, which had their origin far away on the plateau of the Northern Shan States, affected a vast area and disturbed recording instruments throughout the world;[1] they were more local manifestations, experienced over a restricted region, perhaps commencing under or near the delta of the Irrawaddy. As they were not responsible for any loss of life and left no ruins behind them, they were quickly forgotten by the general public, but they deserve serious study none-the-less, for it is disturbing to realise that a great and growing city such as Rangoon, in which large sums are being spent by official agency and private enterprise alike in building construction and general development, is situated on foundations which have not attained permanent stability and are either capable of generating shocks or responding to earth movements from some neighbouring focus of weakness. While this note was being written two further earthquakes were reported to have taken place on the 14th and 15th January 1929, both occurring about the same time, between 4-15 and 4-30 p.m.; the first was of very slight intensity, but the other was more pronounced, while neither lasted more than a few seconds. The questions which naturally occur are whether these shocks are symptomatic of any serious trouble. Are they the forerunners of a really disastrous quake, or do they in themselves indicate a gradual release of pent-up forces by acting as a kind of safety-valve to growing earth pressure or strain? Unfortunately

[1] J. Coggin Brown: "The Burma Earthquakes of May 1912," *Mem., Geol. Surv., Ind.*, Vol. XLII, Pt. 1, (1914).

these and similar queries cannot be answered satisfactorily in the present state of knowledge and it is only by the patient collection of data regarding actual occurrences that it can be increased. There is no efficient organisation recording earthquakes in Rangoon and the only seismograph in the whole Province is dismantled and useless.

In the absence of records it is impossible to tabulate any other local earthquakes of this kind which may have been experienced in recent years. A long series of severe shocks is believed to have damaged many buildings, including the Secretariat, and to have destroyed others, including the old Currency Office in 1895 or 1896, but enquiries which have been made have failed to bring to light any information regarding them.

THE EARTHQUAKE OF THE 10TH SEPTEMBER 1927.

The shocks caused no appreciable damage.

The second shock of the three which took place at 12-5 p.m., 12-47 p.m. and 4-25 p.m. (Rangoon Time), was the most noticeable of the group, though none of them caused appreciable damage. It made small cracks in the crown of an arch in the entrance hall on the east side of the Engineering College, University of Rangoon, and opened up and extended a large existing crack in the north-east corner of the Geological Survey Office, 230, Dalhousie Street. Cracks are also said to have appeared in the arches of the porches of the bungalows occupied by the District Judge and the Superintendent of the Veterinary School at Insein, but there appears to be some doubt about these.

Burma Standard Time.

Standard Time is used in Burma. It is 5 minutes 20 seconds ahead of Rangoon Mean Time, which is 6 hours 24 minutes 40 seconds (96° 10′) in advance of Greenwich Mean Time, whereas Burma Standard Time is 6 hours 30 minutes (97° 30′) in advance of Greenwich Mean Time.

THE EARTHQUAKE OF THE 17TH DECEMBER 1927.

The following general notes on the shock of the 17th December have been compiled from accounts which appeared in the "Rangoon Times" on December the 17th and the "Rangoon Gazette" of December the 19th, 1927.

The shock was the severest which has been experienced for many years. The effects were worst in bungalows and wooden structures where the noise of cracking wood and the rattling of pictures and crockery produced the sensation of being in the carriage of an express train. The main shock lasted about eight seconds. It occurred about 2-30 a.m. and was preceded by three others of minor intensity, which were, moreover, distinctly felt and accompanied by slight noises. The roof of house No. 196 in 27th Street fell on to the road. The walls of some of the Sergeants' quarters at the Mogul Guard were cracked and plaster was dislodged. In the servants' quarters a whole line of bricks was displaced and fell on to the veranda. The Sule Pagoda received a circular crack just below the *hte*. The towers of the Central Fire Brigade and the Lanmadaw Fire Station were cracked. The walls of the upper rooms of the Minto Mansions Hotel were cracked in several places and patches of plaster fell from the ceilings. A building belonging to Messrs. Coombes & Co., in Sule Pagoda Road, suffered several cracks. House No. 600, Merchant Street, was damaged, both the outside and inner walls being badly cracked in several places. The outer wall facing Merchant Street was practically separated from the landing at the top of the stairs, the cement of which was also badly cracked. In the Scott Market, the steel girders were heard grinding together. Many private houses had cracked walls and dislodged plaster but the big buildings seem to have escaped injury.

Account in the "Rangoon Times" of December 17th, 1927.

The earthquake, which lasted several seconds, was immediately preceded by the noise of what appeared to be a terrific explosion. The deep rumbling that accompanied it was startling. It caused general alarm in the town, some people seeking safety in flight to the open spaces while others remained indoors too panic-stricken to move. When daylight came there were few outward signs of its results. The massive ornamentations of the roof of a house in 27th Street were broken off and fell into the road, smashing the cement work over the drain. The premises of the Kemmendine Match Factory Co. had huge cracks in all the walls, while the front wall was leaning forward, almost separated from the rest of the structure. Buildings in the course of construction stood the shock extremely well and beyond the new quarters and other buildings of the General

Account in the "Rangoon Gazette" of December 19th, 1927.

Hospital, facing Canal Street, which were badly cracked in the interior, none of the others suffered any apparent damage. At Government House some brickwork fell from a bedroom ceiling. On enquiry, however, it was learnt that very few buildings, either of business firms or of private residents, had escaped, nearly all having either the walls cracked or the plaster dislodged. Of these the Minto Mansions Hotel seemed to be the worst sufferer, especially in the upper storeys. People residing in the suburbs were greatly frightened as the houses shook to such an extent that not only was crockery and glassware broken but articles of furniture were actually moved. Those who were awake when the occurrence took place state that the earth first moved up and down and then horizontally.

Details of Official Enquiry.

The accounts already quoted and my own personal experience led me to attempt to obtain further information regarding the extent of the affected area, the phenomena accompanying the quake and the damage it had caused. With this object in view I wrote letters to the editors of the "Rangoon Gazette" and the "Rangoon Times" and invited interested readers to send me particulars of the following:—

(1) Full name and address.
(2) Locality where observations were made.
(3) Situation of the observer, whether indoors or in the open air, lying down, sitting, standing or moving.
(4) Exact time at which the shock was felt.
(5) Number of distinct shocks.
(6) Character of the shocks, whether merely tremulous vibrations, not distinguishable as separate movements or noticeable to-and-fro movements.
(7) Apparent direction of the shocks, judged by the fall of the light objects, hanging lamps or movements of water.
(8) Sound phenomena.
(9) Intensity of the shock, whether hardly felt or distinctly felt.
(10) Effect of the earthquake; such as particulars of objects overturned, their size, position and direction of fall. Details of cracks in buildings with sketches showing their direction and an accurate record of the affected walls, if possible.

I also addressed the Deputy Commissioners of various districts while the Financial Commissioner (Reserved Subjects) caused further enquiries to be made on my behalf. On the whole, the response to my requests was very poor.

Seismograph records.

The officers of the Meteorological Observatories in Alipore (Calcutta), Colaba (Bombay), Colombo and Kodaikanal (Madras) who were requested to inform me whether the earthquake was registered by any of the seismographs under their charge replied as follows:—

The Milne Horizontal Pendulum Seismograph, recording the east-to-west component at Kodaikanal, showed only a very small widening of the line at 1 h. 39 m. 8 s. (Indian Standard Time) on the 17th December 1927.

The Milne-Shaw Seismographs in the Colaba Observatory recorded feeble tremors at 3-30 a.m. (Bombay Local Mean Time) on the 17th December. As none of the phases was clearly shown it is impossible to state definitely whether these tremors were associated with the maximum movements in the long-wave phase of the Rangoon shock.

The Superintendent of the Colombo Observatory could furnish no figures for tremors on the morning of December the 17th, 1927. Several rather curious movements were recorded on the 16th December, but from 5 p.m. (Ceylon Standard Time, 11-30 Greenwich Mean Time) on that date until the chart was developed on the 17th morning, the trace was smooth. Because of this the instrument (Milne-Shaw type with pivot northward) was dismounted on the morning of the 17th, when its boom was found leaning right over to the west and fouling the solenoid. The jerks on the morning of the 16th December were not of the ordinary seismic type, nor could they be explained by any of the usual mechanical interferences. Their direction was to the west in most cases, though between 7 and 8 a.m. on the 16th, the trace showed an apparent drift to the east without a sharp jerk. The latter, unlike the jerks, might have been caused by faulty drive in the clock, as the chart carriage moves from east to west. The trace on the 15th-16th was much more even and the Superintendent is inclined to suggest that impulses of a distinctly shorter period than the instrument is tuned for, occurred between 7 a.m. and 5 p.m. on the 16th, resulting in the boom being practically jammed from 5 p.m. on that date until it was reset on the 17th, but whether these impulses

were in any way connected with the Rangoon earthquake is a question on which no opinion can be offered.

The earthquake was not recorded by any of the seismographs in the observatories at Alipore (Calcutta) or Simla and it is regrettable that the one in the University College at Rangoon, which might have furnished so much useful information, is not in order, a lamentable state of affairs which should be remedied as soon as possible, especially in view of the recurrence of sensible earth tremors in Rangoon early in 1929.

Earthquakes in the Dutch East Indies on the same dates.

The "Rangoon Times" of the 6th January 1928, quoting from the "Times of Malaya", reported that on the night of the 16th December heavy earthquake shocks were felt in the neighbourhood of Donggala (Celebes), where the walls of the Assistant Resident's house collapsed. At Poloe the market sheds and part of the pier were destroyed. At Biroe-Maroe the market sheds were completely destroyed and the Regency Offices badly damaged. A small tidal wave wrecked a number of native houses on Poloe Bay where 14 people were killed and 50 injured. The damage was estimated at f. 50,000.

It occurred to me that there might be some connection between the Rangoon quake and this calamity and I communicated with the Director of the Geological Survey of the Netherlands East Indies, with the Chief Commissioner of the Andaman and Nicobar Islands and with the Senior Government Geologist in the Federated Malay States. Both the latter officials informed me that no earthquake shocks were noticed in the territories with which they are concerned on the date mentioned. The Director of the Geological Survey in Bandœng handed on my letter to Dr. Visser, the Sub-Director of the Royal Magnetic and Meteorological Observatory in Weltevreden (Batavia) which undertakes the instrumental observation and registration of earthquakes in the Dutch East Indies. Dr. Visser courteously replied to my letter as follows:—

"The earthquake of Donggala (N. W. Central Celebes), occurred on December 1st, 1927, and was registered by our seismographs at 4 h. 40 m. 51 s., G.M.T. A faint shock (without seismograms at Batavia) occurred in the same region on December 16th, at 22 h. 30 m. G.M.T. (4 h. 54 m. Local Rangoon Time). The time difference with the Rangoon quake is much too large to presume

any connection. No earthquakes were registered or reported in Java at the time mentioned in your letter.

On September 10th, (the date of the earlier Rangoon quakes), earthquakes were reported from Pasoerocan (East Java) at 9 h. 25 m. and 11 h. 25 m., G.M.T. They were not registered at Batavia and cannot have anything to do with the Rangoon quakes of that date. At about 23 h. Local Time (being also Local Rangoon Time) an earthquake occurred in Atjeh (North Sumatra) but it is nearly impossible that this shock should have been felt in Rangoon too. It was not registered at Batavia and therefore the reports refer only to a faint shocks."

Dr. Visser's observations prove therefore that there was no connection between the quakes and those which took place in the Dutch East Indies on the same dates. No apology is needed, however, for investigating the possibilities of such a relationship in view of the resemblances in stratigraphy, the probable continuity of major geological structures and the inclusion of both countries in the same region on seismic maps of the world.

The replies received from the Deputy Commissioners soon made it apparent that the earthquake had not been experienced over a large region and that the land area of the felt-shock was in fact quite circumscribed.

Limits of the Shock.

It was noticed in the Hanthawaddy, Insein and Tharawaddy districts, in the Maubin and Yandoon townships of Maubin, in the Dedaye township of Pyapon, while it was slightly felt in the Kyangin township of the Henzada district. In none of these townships was any damage caused. The following districts reported that the shock was not felt: Amherst, Bassein, Kyaukpyu, Mergui, Prome, Sandoway, Tavoy, Thaton, Thayetmyo, Toungoo. No reply was received from the Myaungmya district.

From the very meagre information available an attempt has been made to show on the sketch map accompanying this article, the approximate outer limits of the area over which the shock was generally noticed. It probably corresponds very roughly with isoseist IV-V on the Rossi-Forel scale. The officers in charge of the districts adjoining Hanthawaddy, Pyapon, Maubin, Insein, Tharrawaddy and Henzada all report that the shock was not felt in their respective charges, with the exception of Myaungmya. The area has to be extended to the north-west in the way it is delineated, to

include Kyangin, the northernmost township of Henzada, though to do this has made it necessary to include the south-eastern corner of Henzada and a small portion of the extreme north-eastern section of Bassein, where it was not felt or perhaps was so slight as to pass unnoticed. The definite statements of the Deputy Commissioners of Pegu and Prome, made after due enquiries that the shock was not experienced in their districts, limit the area on the west.

Masonry buildings are exceptional outside the large towns of Lower Burma, and the majority of the people live in wooden houses or bamboo huts of flimsy construction. Slight earthquake shocks, approaching the limit of human sensibility, are accordingly liable to pass unobserved. In the Kyangin township the shock was only "slightly felt". In the Maubin and Yandoon townships of Maubin it was also described as "slight" and caused "no damage whatever". In the Dedaye township of Pyapon it caused no damage and only lasted two seconds. It seems reasonable to suppose that, wherever the disturbance originated, it had dwindled down and was approaching the extreme limit of sensibility by the time it reached these areas.

The Deputy Commissioner of Hanthawaddy (in which Rangoon lies) kindly consulted the Sub-divisional and Township Officers, the Executive Engineer of the Delta Division and the Presidents of the Syriam and Thongwa municipalities. They all replied that no serious damage was caused by the shock. It would thus appear to have faded away quickly in the deltaic region, south and south-east of Rangoon towards the sea.

The area indicated on the map encloses approximately 5,000 square miles and it will be noticed that a line joining Kyangin and Dedaye, the most northerly and southerly points from which reports were received, passes exactly through Yandoon, while Maubin lies within a short distance of it on the west. This line is practically parallel to the main trend line of the southern extension of the Pegu Yoma and to the general direction of the Irrawaddy river between Myanaung and Yandoon.

Geology.

The higher ground rising from beneath the plains, some 16 miles to the south-east of Rangoon, where it is crowned by the Syriam and Shwe Dagon Pagodas, continues as an elevated ridge in a north-by-west direction for about 30 miles before it joins the ranges of the Pegu Yoma of which it is an extension.

With the exception of this ridge and possibly a small portion of the Kyangin township of Henzada, occupied by Eocene strata, the whole region affected by the earthquakes lies on the alluvial deposits of the delta.

The part of the prolongation of the Yoma which is of interest here contains a core of rocks of Pegu (Miocene) age flanked by younger deposits which Mr. Theobald,[1] who surveyed the region between 1865 and 1870, mapped as Lower Delta Alluvium, but which later geologists are inclined to believe corresponds at least in part with the Irrawadian series (Pliocene) of Central Burma. This question is not likely to be settled until the southern portion of the Pegu Yoma has been resurveyed and, in any case, has no bearing on present considerations.

The Pegu beds of this region consist generally of soft, unfossiliferous, light coloured sandstones and shales with occasional bands of harder, calcareous sandstone. Their strike fluctuates from a few degrees east of north to a similar angle west, and they dip beneath the younger rocks on either side. Theobald pointed out long ago how a broad belt of sandy deposits skirts the Yoma, occupying the position of and replacing coarser gravels found further to the west. These sandy accumulations are relatively more important in the south, and in the area under discussion, shroud and almost conceal the Pegu rocks, which only here and there betray their existence beneath them, as on the Pagoda hill in Rangoon and where the Syriam ridge finally disappears, on the banks of the Hmanwon Chaung.

The most recent work on these rocks is that of P. Leicester, in connection with the Rangoon Water Supply Surveys.[2] In the neighbourhood of Wagyaung about 40 miles due north of Rangoon and on the southern fringe of the Yoma proper, he found the boundary between the Pegus and the overlying rocks quite ill-defined. The latter are made up of a lower division of shales, soft, shaly, micaceous sandstones with bands of hard clay and beds of sand, overlain by an upper group of current-bedded sands, sand-rock with clayey layers and soft, laminated, micaceous sandstones. In places the sand-rock prevails and contains nodules and whisps of clay, suggesting deposition in an estuary or lake. The structure forms a series of small anticlinal and synclinal flexures and especial attention is

[1] W. Theobald: "On the Geology of Pegu". *Mem., Geol. Surv., Ind.*, Vol. X, Pt. 2 (1873).

[2] General Report; *Rec. Geol. Surv., Ind.*, Vol. LXII, p. 38.

drawn to numerous faults some of which can be traced for a considerable distance. Mr. Leicester believes it quite possible that the Irrawadian series (Theobald's Older Delta Alluvium) passes gradually into the Estuarine Alluvium hereabouts without any visible break.

These are the only solid rocks exposed within the area affected by the earthquakes, the remainder, and by far the greater portion is covered by alluvial clay, that wide-spread formation which, with the exception of trifling patches of newer alluvium and recent deposits of sand and silt in the beds and about the banks of existing streams, covers the whole delta of the Irrawaddy and the plains of the Sittang valley from north of Toungoo to the sea. The clay is very homogenous, a little more sandy in some places than in others, with occasional thin beds of sand irregularly and sparingly dispersed through it. Theobald believed that the clay was of estuarine origin, deposited in a shallow gulf when the land stood at a lower level above the sea than it does to-day, and not the result of small increments of sediment left by the river during its flooded periods, to which it is still popularly and erroneously ascribed. The deltaic deposits of the plains are of great thickness, but as the foothills of the Yoma are approached, the alluvial blanket thins out, yet, even at Wagyaung, according to Mr. Leicester, at an elevation of 75 feet above sea-level, the clay is still 15 feet thick.

Such are the strata in or under which a cause of the Rangoon earthquakes is to be sought.

Time of the shock.

Earlier commentators on Indian earthquakes have described the difficulty and sometimes the impossibility of obtaining exact times. The present case is no exception to the rule. The earthquake was stated to occur by competent observers in Rangoon at times varying between 2-27 and 2-35 a.m. The average of all the times received is 2-29 a.m. The only instrument affected by the earthquake in the Port Commissioner's Observatories was the driving clock of the anemograph in the Tidal Observatory near Brooking Street wharf, which, according to the Deputy Conservator of the Port, stopped at about 2-25 a.m. There are no standard clocks in the office of the Principal Port Officer, Burma. The record of the 42-inch Venturi-Water Meter of the Rangoon Corporation, a copy of which was kindly supplied by the Chief Engineer, shows that the recording pen was violently

disturbed about the same time. It is unfortunately impossible to get closer to the exact time than this, and this figure is of course valueless for the usual accurate seismological calculations based on time determinations.

Earthquake sounds.

A characteristic feature of the shock was the loud noise which accompanied it, yet it does not appear to have been heard by all observers. This, however, is not by any means unusual and is explained by its low pitch being outside the audibility of some persons. To my own ears it seemed like a loud explosive bang and was followed immediately by the quake itself. Others have compared it to a "terrific" or "violent" explosion, to the noises of rapidly moving railway trains and motor buses and to deep rumbling. Particularly interesting is the account of one observer who happened to be awake at the time and declared that the sound came from the west preceding the quake, increased in volume during the actual movements which lasted for 10 seconds, finally diminishing in volume and ceasing.

According to Davison, "Earthquakes and earthsounds are manifestations, differing only in degree and in the method in which we perceive them, of one and the same phenomenon.[1]"

Intensity of shock.

Practically the whole of the available evidence is derived from Rangoon which was perhaps as severely shaken as any part of the affected area. In attempting to measure the intensity of the shock the Rossi-Forel scale is used. It classifies earthquakes into the following 10 groups:—

(1) Recorded by a single seismograph, or by some seismographs of the same pattern, but not by several seismographs of different kinds; the shock felt by an experienced observer.

(2) Recorded by seismographs of different kinds; felt by a small number of persons at rest.

(3) Felt by several persons at rest; strong enough for the duration or direction to be appreciable.

(4) Felt by several persons in motion; disturbance of moveable objects, doors, windows, cracking of floors.

(5) Felt generally by everyone; disturbance of furniture and beds; ringing of some bells.

[1] C. Davison, "Manual of Seismology," 1921, p. 63.

(6) General awakening of those asleep; general ringing of bells; oscillation of hanging objects, stopping of clocks; visible disturbance of trees; some startled persons leave their dwellings.
(7) Overthrow of moveable objects, fall of plaster, ringing of church bells, general panic, without damage to buildings.
(8) Fall of chimneys, cracks in the walls of buildings.
(9) Partial or total destruction of some buildings.
(10) Great disasters, ruins, disturbance of strata, earth fissures, rock falls.

The varying conditions of architecture and domestic life in the East do not allow of exact correlation with this scale, drawn up as it was for use in a European country. R. D. Oldham, C. S. Middlemiss and others have therefore grouped intensities II and III, IV and V, VI and VII together in pairs, counting them as folllows :—

Intensities.	Definition.
II-III Rossi-Forel	Felt by a few sensitive people, lying down or favourably situated.
IV-V " "	Generally noticed, no damage.
VI-VII " "	Universally felt, disturbance of furniture and loose objects. No damage to buildings except in rare instances to brick-built structures.

Reasons for giving details.

As C. S. Middlemiss wrote in his account of the Calcutta earthquake of 1906 :—" It may be thought and commented on by some that the details which follow are a monotonous series of uninteresting and frequently similarly expressed experiences. This is in a great measure true." My reason for putting the present ones on record agrees with his in that they form the only evidence we have of an earthquake which came very near to being disastrous to the chief town in Burma. If not recorded now, their details must pass into oblivion, since the evanescent character of most earthquake effects always precludes a resurvey of an area affected by a seismic disturbance.[1]

[1] C. S. Middlemiss: "Two Calcutta Earthquakes of 1906," *Rec., Geol. Surv., Ind.,* Vol. XXXVI, p. 216.

With some exceptions, modern, well-built buildings did not suffer. Cracking of walls seems to have been confined mostly to old brick structures and to those which lie on reclaimed ground or on the alluvium of the river. It is a well known fact that earthquake shocks are felt more severely on soft ground than on hard or compact rock. This may explain to some extent the escape of the residential portion of Rangoon on the higher ground to the north of the city proper, and the preservation of the Shwe Dagon while the Sule Pagoda in the City was injured. At the same time the average type of timber or timber-framed, brick-nogged house, such as those usually occupied in the residential quarters of Burmese towns, is well adapted, as I have shown elsewhere, to withstand earthquakes.

Damage in Rangoon.

Report of Executive Engineer, Rangoon Division.

Dufferin Hospital, Mission Road, Gynæcological Ward. On the ground floor slight cracks were made in the partition walls below the junctions with the steel beams. In the annexe passage one of the outer arches developed a thin crack. On the first floor, slight cracks were seen above the arch of the central lobby and in the three outer arches of the back veranda. On the second floor, a continuous, horizontal, hair-breadth crack developed in the rear wall of the front veranda, nine inches below the ceiling. There were similar hair cracks at the springing of the lintels in the veranda. A minute crack formed at the junction of the partition wall of the wards with the main ward but it did not continue into the dado tiling. Four of the opaxite sheets in the operating theatre were cracked as were also the corners of two asbestos sheets in the ward ceiling.

Dufferin Hospital, Main Maternity Ward. The cracks in this building were most conspicuous in every ward on the second floor. They developed at the junctions of lath and plaster ceilings and walls and of the main walls. In two instances the latter had irregular cracks across them. Hair cracks were also visible in some of the veranda cross-arches. On the ground and first floors there were a few slight cracks near window *choukhats* and junctions which were hardly visible to the naked eye.

Report of the Rangoon Estate Officer.

No serious cracks were found except in the Currency Office and in the Office of the Conservator of Forests, Utilization Circle, in Dalhousie Street. In the former case the bonding of the brick work was found to be faulty and there was practically a vertical joint in the wall,

Generally speaking the damage done was very slight, limited chiefly to the cracking of plaster, particularly at the junction of walls with ceilings where the wall had moved independently of the roof.

Office of the Conservator of Forests, No. 46-A, Dalhousie Street. A three-storied, masonry structure of Indian design and construction, of rectangular shape, measuring about 90 ft. by 55 ft. The long walls face north and south. They average about 2 ft. 6 ins. at the top. All the internal work is made of wood. The building has no cross walls whatever inside, and is merely a large masonry shell, filled with wooden constructions. The tremor apparently travelled from west to east and caught the building end-on. There was considerable movement of the end walls, facing east and west, as shown by breakages at the junction of the ceilings. A fairly serious crack developed at the north-east corner in the long wall, evidently caused by the movement of the short east wall. The building had to be stiffened up with steel tie rods at the first and second floor levels, while angle irons were fixed outside it, along the first floor cornice.

Report of the Port Commissioners.

The earthquake was responsible for slight damage only to the following buildings belonging to the Commissioners for the Port of Rangoon. An archway facing east and west of the ground floor of "Riverholm," Strand Road, was cracked near the crown. The old Port Commissioner's House, at Barr Street Jetty developed cracks in the walls while plaster was broken down. Both these brick buildings are situated between Strand Road and the River and were built some 20 years ago. A number of cracks were caused in the arches and walls of No. 13 Cheape Road and plaster was dislodged from the ceiling; it is a brick building, 4 years old.

Reports of the Building Engineers, Corporation of Rangoon.

The Assistant Buildings Engineer of the Rangoon Corporation reported as follows:—No. 600/602, Merchant Street. An old, two-storeyed, pucca building, measuring 57½ by 100 feet facing south, with a frontage of 100 feet facing west on Maung Taw Lay Street. There were numerous cracks in the front, intermediate and rear walls and also in the western side wall. Most of them were through arches and lintels over doorways, windows and passages and extended from the floor level to the roof. The southern wall was also rather badly damaged at the junction of the first and second storey walls; the external layer of bricks at the lower portion of the second storey

wall was greatly crushed. The pucca floor of the first storey was damaged at this point and had cracked away from the wall. Only the western half of this building was affected and there were no very perceptible cracks in the eastern portion. The shock appears to have travelled in two directions E.-W. and N.-S. but the latter was the more pronounced. —No. 97/81, Morton Street. A two-storeyed pucca building about 25 by 50 feet, facing east in the block between Dalhousie and Canal Streets. Cracks over the doorways and in the western wall. No cracks in the front or side walls. Shocks apparently travelled from N. to S. —No. 68, 6th Street. A one-storeyed pucca godown facing west, measuring about 250 by 50 feet in the block between Dalhousie and Canal Streets. Arches over doors and windows, in front and rear walls, within 25 feet of the northern end, cracked through. No cracks in northern side wall. Movement apparently from N.-S. —No. 78, 5th Street. A two-storeyed pucca building, 25 by 50 feet, facing west, in the same block. Two cracks in the front wall from floor to roof, one of which passed through an arch and the other by the side of a front pier near its junction with the wall. No cracks in the east or side walls. Direction of shock N.-S. —No. 6A, Fytche Road. A two-storeyed, pucca building in a large open compound. Numerous cracks in all the walls, from top to bottom, chiefly over arches and at the corners of doors and windows. —No. 29, Kemmendine Strand Road. An old single-storeyed, pucca building, facing west, with a lean-to kitchen behind. The rear wall of the main building was badly cracked in three places, through arches over doors and windows. A crack, ½ inch wide, separated the main building and the kitchen walls. Direction of shock apparently N.-S. – Maternity Shelter, Kyaikasan Road. A single-storeyed, pucca building, facing east. Numerous cracks in the north and west walls from floor-level to roof, mainly through lintels and corners of doors and windows. One slight crack in eastern and none in southern wall. Floor along northern wall very badly cracked, fissure running E.-W. Though the weight of the walls and foundations is on the northern side of this fissure, its southern side was about one inch lower than the other. The building had been erected on reclaimed soil.

Reports of the Buildings Inspectors, Rangoon Corporation.

No. 40, 52nd Street. A two-storeyed, pucca building. Northern side wall sank a little and cracked throughout its length, particularly where it meets other walls. —No. 183, Thompson Street. A two-storeyed, semi-pucca building. Rear wall cracked.

—Nos. 119/121, 40th Street. A three-storeyed, pucca building. Lavatory walls cracked and separated from main walls, due to absence of proper bonding. —No. 6, Barr Street. A three-storeyed pucca building. Cracked at the crowns of the arches in the south side wall of the third storey. —No. 84, Dalhousie Street. A three-storeyed pucca building. Both ends of the front wall over the arches of the third storey cracked. —No. 600/602, Merchant Street. A two-storeyed, pucca building, measuring about 57½ by 100 feet. Cracked through the arches over doorways and windows and the walls above them. Front wall badly damaged. Pucca wall on first floor-level partially cracked. —Nos. 22 and 24, 29th Street. The pucca wall between these two houses was cracked from top to bottom. —No. 33, 29th Street. An old, three-storeyed, pucca building with a frontage of 50 feet. Four slight cracks in the front wall. —Nos. 482/484, Dalhousie Street. An ornamental block at the east end of the parapet was dislocated and fell.

Other Rangoon Reports.

J. Watson, 70, Phayre Street, Rangoon, reported as follows:—In bed, top flat of 5 storeys. One shock which caused bed standing north and south to rock. Awoke and clutched both sides of it. Shock was distinctly felt and followed by tremors. Direction E.-W. Soda-water bottles standing on pantry floor fell to east. Two wine decanters standing against western side of a cabinet, fell to east. A reading lamp fell to west. Ten buildings belonging to Mr. Watson's firm were slightly damaged. More damage was done to two buildings in the Ahlone and Mission Road area than in the City itself.

Major L. B. Clarke, R.A.M.C., 2, Cheape Road, Rangoon:—Asleep in wooden bed, lying E.-W., in upper room of old wooden bungalow with two floors. Time 2-35 a.m. Awakened by sound like a violent explosion; sudden upheaval of building followed, then a series of diminishing vibrations lasting a few seconds. First shock was vertical upheaval, sufficient to raise floor several inches. Very distinctly felt and quite separate from the subsequent smaller, swaying vibrations. Direction same as shocks of September 10th, definitely from S. to N. Sound like a big explosion followed by a gradually diminishing rattling. Whole movements and sound compared to similar effects of "camouflets"[1] used in active under-

[1] A 'camouflet' is a mine containing a small charge of powder placed in a wall of earth between the galleries of opposing forces, so as, in exploding, to bury suffocate or cut off the retreat of the miner of the opposite side; a 'stifler'.

ground warfare during the War. Plaster fell from ceiling. A crack in a concrete foundation supporting a wooden porch pillar. Nothing broken and no serious damage.

F. Skeen, 25, Tamway Road, Rangoon. Asleep in bed. Awakened by violent movements "as if the whole house was bobbing up and down vertically." One shock, distinctly violent. Duration 4 to 5 seconds. On arrival at office (Messrs. Rowe and Co.'s building) found clock stopped at 2-27 a.m. Books from shelves on south wall thrown off some distance to north. Movement N. to S.

Four assistants of Messrs. Rowe & Co., by courtesy of Mr. Skeen, Tamway Road, Rangoon. Distinct movement from north to south. North and south walls of house rather badly cracked. Plaster fell in bedrooms. Roof beams cracked. If shock had continued believe roof would have collapsed.

R. K. Anderson, 17, Godwin Road, Rangoon. Awake in bed. Time 2-30 a.m. Series of shocks which felt like "lying in a railway train on to which a number of carriages are shunted." Movements very noticeably to and fro and from W. to E. Sound came from west and increased in volume as though a motor bus was approaching at a very high speed. Then quake commenced. Heavy almirahs groaned loudly. Doors rattled. Wooden building cracked considerably. Left bed and went on to south veranda, heard sound travelling away to east, diminishing in volume and then ceasing. Sound lasted 40 seconds. Movements at least 10 seconds. Distinctly felt, caused giddiness. No objects overturned.

Captain H. N. Shivapuri, I.M.S., Halpin Road, Rangoon. Sleeping. Aroused by terrific sound followed by definite earth movement lasting a few seconds at 2-32 a.m. Thought someone had jumped into bedroom through window. Shock described as severe. Remembers many earthquakes in various parts of India but never experienced such noise, rumbling and shaking.

B. C. Bennee, Tamwe Village, Kyaikkasan Road, Rangoon. Asleep. Awakened by banging of door. Shock described as deliberate and severe. Direction either S.W.—N.E. or S.—N. No noise.

U Sein Daing, Bar-at-Law, 3rd Additional Magistrate, Rangoon. The deep rumbling accompanying the earthquake was startling. The whole structure of his wooden house cracked and he thought it would fall. Duration 5 seconds. Direction N.—S. Severest shock

Rangoon has experienced for 32 years. Sule Pagoda received a circular crack under the *hte*.

A. B. Corrie, "Newland," Kamayut. New house about 6th mile along Rangoon-Insein Road; two-storeyed, brick structure, with concrete floors and roof. Asleep in wooden bed on upper storey. Awakened by intense, very noticeably felt, tremulous vibrations which slowly grew less and ultimately died away. Duration perhaps 3 to 4 seconds. Compares sound and sensation to close passing of a very heavy, rapidly driven train.

J. Coggin Brown, 16, Prome Court. Asleep. Awakened by loud noise. Thought a big explosion had taken place at the oil refineries. Rapid shaking of building followed. Duration about 5 seconds. Realised it was an earthquake. Rushed to door of room in case main shock was to follow. Time 2-28 a.m. (approximately). Direction from S.S.E., from swinging of hanging lamps. Nothing overturned. Birds, dogs and servants very alarmed. Residents in Tank Road left houses for gardens. Shock disappeared as quickly as it arrived; no after tremors noticeable. Horizontal hair cracks in upper storey of Bachelors' Quarters of Prome Court, near junction of roof and walls. Loose bricks fell from top of jail walls in no well-marked direction.

SUMMARY.

Summing up the available evidence it is concluded that the shock attained an Intensity of VII on the Rossi-Forel scale in Rangoon. Damage to buildings in the East is usually regarded as commencing lower down the scale than it does in Europe, but on the other hand, the type of wooden-framed structure commonly used in Burma, weighs against the wholesale application of such a principle in this country. The rare, severe cases of cracking in solid brick buildings which necessitated immediate remedies, are regarded as exceptional and not sufficient to justify the use of Intensity IX in this description. These, and a few other instances of widely developed cracking may be accounted for by age, bad design, poor workmanship and location on reclaimed soil. Earth sounds were heard before, during and after the shock, the accompanying one being of an unusually loud, explosive character. The shock was a very sudden one and it is uncertain, owing to its occurrence in the early hours of the morning, whether it was preceded by sensible tremors or not. It was succeeded by fainter, swaying

vibrations. The time was about 2-25 a.m. and the duration quite short, perhaps not more than 5 or 6 seconds. There is the usual want of congruity in the recorded observations on its direction, though the majority give it as N. and S.

Owing to the absence of the necessary data, both personal and instrumental, it is not possible to draw isoseismal lines on the map, or to attempt to calculate such elements of the wave motion as the velocity, period, range or acceleration.

EARTHQUAKE AT SHWEBO ON 15TH/16TH MARCH 1927.

The Executive Engineer of the Shwebo Canal Division, in Upper Burma, when informing me that the Rangoon shocks of September and December 1927 were not felt in his division, mentioned that a distinct shock was experienced in Shwebo about midnight on the 15th/16th March 1927 and resulted in a Government building being damaged.

Cause of the Rangoon earthquakes.

Attempts to find a distant origin for the Rangoon earthquakes have failed, neither can they be accounted for by any kind of volcanic action, while the theory that they may be due to the subsidence of submarine talus is not plausible. They appear therefore to be of a local tectonic nature but as already pointed out in the paragraphs dealing with geology, most of the affected area is covered with alluvial deposits of great thickness which effectually hide the structure of the rocks below them. It is hopeless therefore to seek for any particular line of weakness, the movements of which may have been responsible for the disturbances.

The Pegu Yoma is not a single mountain chain but is built up by a number of more or less parallel ranges of varying height and extent. They reach an elevation of over 2,200 feet about latitude 18° but the portions dealt with here probably do not exceed 800 or 900 feet above sea level and average perhaps a quarter of these heights. The geological structure is simple and although faulting is known to occur it is not complex, complicated, or in any way comparable to the Himalayan varieties which cause world-shaking and disastrous quakes there from time to time.

Yet there is much evidence that the Irrawaddy delta and the hilly regions bordering it are not quiescent, in the sense that they have attained permanent stability. Geologically speaking the Pegu

Yoma is young—a fact which did not escape Theobald's astute observation. "Indubitably," he writes, "the Pegu Yoma could hardly have taken shape and form before the later Tertiary period or have experienced its final elevatory movements before the post-Pliocene period, *if indeed it is safe to infer that such have even now ceased, a view I am inclined to question.*"[1]

If it be true as Theobald implies, that the earth movements which raised the beds forming the Pegu Yoma from the bottom of the sea, and crumpled them into the gentle mountain folds which we know to-day, are still operating, we have a sufficient general cause at hand, to explain the quakes which occasionally shake Rangoon and neighbouring regions, though we are unable to point to any single plane, friction along which, caused by fault growth, might engender such movements.

Later geological research has abundantly confirmed Theobald's views, though without adding much new evidence to support them. It is only necessary to indicate briefly the chief arguments here. Raised beaches occur on the Arakan coast above present tide limits, containing the remains of marine organisms still living in the Bay of Bengal. These prove an elevation of the land in recent times. The older, alluvial clay of the Irrawaddy delta is believed to be of estuarine or marine origin. It is destitute of remains of fresh water or land molluscs, it is peculiarly homogenous over a great area and could hardly have been formed by river action. It was probably laid down in much the same way as similar deposits are forming in the Bay of Bengal to-day from the silt-laden waters poured into it by Burmese rivers. There is an entire absence, with one trifling exception, in the actual channels of the Irrawaddy of any fluviatile group of beds above the older clay, comparable with the younger alluvium of the great rivers of India. This definitely proves that no subsidence is taking place while if it be admitted that the older alluvial clay is of estuarine origin, it follows that a gradual elevatory movement has taken place causing the sea to recede to its present limits.

P. Leicester has observed that the alluvial clay is from 15 to 30 feet thick up to 75 feet above present sea level 40 miles north of Rangoon. He has also pointed out that at Wagyaung, 40 miles north of Rangoon, the Ngamoyeik Chaung and the lower portions

[1] *loc. cit.*, p. 36.

of its tributaries flow in straight, steep-banked channels about 25 feet below the surrounding general plain level. He believes this is due to uplift, increased rainfall or catchment, but the former is probably the true cause.

It is concluded therefore as probable that the Rangoon earthquakes originate in forces of uplift causing movement along lines of weakness below the deltaic alluvium. It seems possible that one of these lies not far below the surface in the vicinity of Rangoon. Apart from its scientific aspects the subject is one of great practical importance to the city and it cannot be urged too strongly that it should receive more attention, particularly as regards the systematic registration of all perceptible quakes, and the restoration of the existing seismograph to a working condition in order that the fainter tremors may be tabulated and studied.

THE EPICENTRE OF THE NORTH-WEST HIMALAYAN EARTHQUAKE OF THE 1ST FEBRUARY, 1929. BY A. L. COULSON, M.SC. (Melb.), D.I.C. (Lond.), F.G.S., *Asssistant Superintendent, Geological Survey of India.*

1. Introduction.

De Montessus de Ballore.

F. de Montessus de Ballore has noted [1] that the "neighbourhoods of Peshawar, Rawalpindi, and Attock are very unstable, without having suffered to any great extent. A great dislocation, crossed by numerous secondary faults, separates the tertiary basin of Rawalpindi from the ancient rocks. So we can suppose that the forces from which these faults have proceeded manifest themselves still in the shape of earthquakes. Ruins, at least partially of seismic origin, are seen in many ancient castles built on the hill-tops."

Additional proof of the instability of this area has been given by reports received from meteorological observers in northern India, of an earthquake shock of moderate intensity which occurred about 22 hours 45 minutes (Indian Standard Time)[2] on the 1st February, 1929.

[1] *Mem. Geol. Surv. Ind.*, XXXV, Pt. 3, 1904, p. 6.
[2] Indian Standard Time is 5 hours 30 minutes ahead of Greenwich Mean Time.

2. Reports of Meteorological Observers.

Situation of Observers.

The meteorological observers in question were situated at the places shown in the accompanying sketch-map (Fig. 1) and listed in the following table, which shows, also, the times of the shocks in Indian Standard Time, their number and their duration.

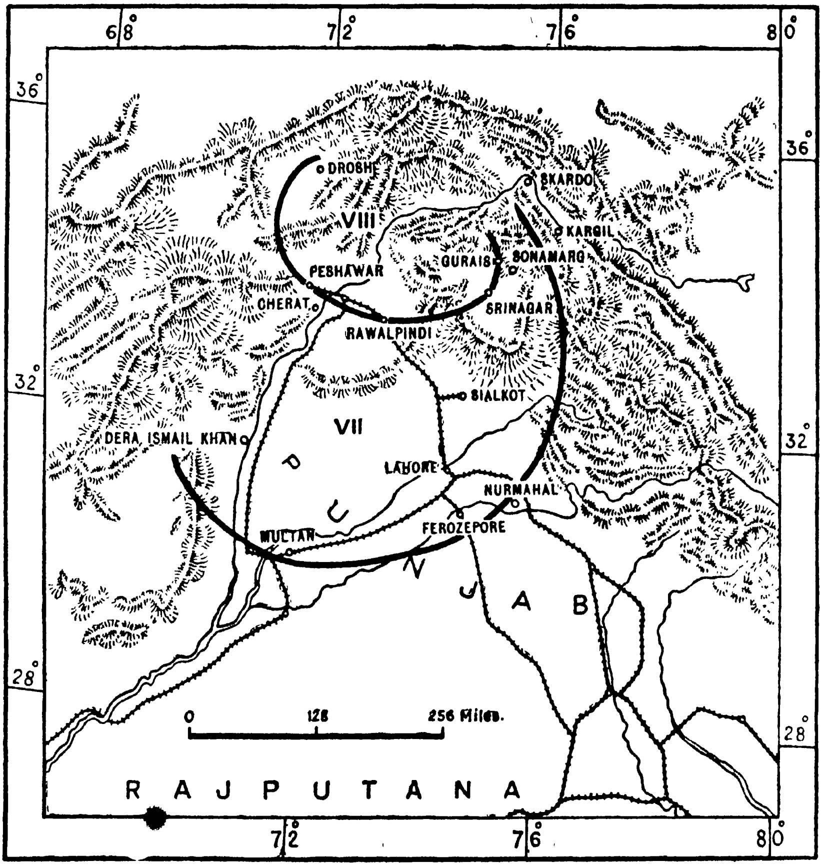

FIG. 1. Sketch-Map showing the places in Northern India from which reports of the earthquake of the 1st February, 1929, were received.

Place.	Indian Standard Time.	Number of Shocks.	Duration of Earthquake in Seconds.
Drosh	22·45	1	90
Rawalpindi	22·50	(10 serious) (30 slight)	150
Peshawar	22·50	4	20
Srinagar	22·49	2	25
Gurais	22·45	2	26
Cherat	(?)22·30	..	75
Sialkot	22·45	3	50
Lahore	22·45	1	30—45
Skardo	22·45	4	5
Sonamarg	22·45	3	7
Ferozepore City	22·45	2	60
Dera Ismail Khan	22·47	..	25
Multan	22 52	3	5
Nurmahal	22·45	..	..
Kargil	(?)23·0	1	35

Position of the Epicentral Tract.

The reports indicate that the epicentral tract lies in the area between Drosh, Rawalpindi, Peshawar, Srinagar and Gurais as here the intensity of the shock was sufficient to crack the walls of buildings and to cause even greater damage. This is shown on the map (Fig. 1) by the approximate isoseismal line, Intensity VIII by the Rossi-Forel scale, which is drawn through these places. The pinnacle of the biggest Jam'a Mosque and several houses are reported as being damaged at Peshawar; a portion of the tower of the Lower Drosh Fort and part of the wall inside the Upper Drosh Fort fell down.

Thus the approximate position of the epicentre is about 1,115 miles (1,795 km.) from Bombay, 1,270 miles (2,040 km.) from Calcutta and 1,740 miles (2,800 km.) from Kodaikanal.

It is interesting to note that de Montessus de Ballore[1] has recorded the following epicentres within the present epicentral tract, the numbers in parenthesis indicating the number of shocks given by him:—Attock (2), Baramula (83), Gurais (1), Koori (2), and Srinagar (8).

With the exception of Nurmahal and Dera Ismail Khan, it is stated for all the other places shown on the map (Fig. 1) that the intensity of the shock on the 1st February was strong enough to be felt by persons at rest;[2] to make doors and hanging objects swing, windows rattle, and floors creak; and to throw down loose objects (except at Skardo). This indicates a widespread intensity of VII on the Rossi-Forel scale. With reference to the shock at Dera Ismail Khan, of which, unfortunately, the usual report was not received, it was stated that the menials in the local Post and Telegraph office considered the shock to be the "heaviest shock in their memory;" similarly there is a lack of definite evidence as to the intensity of the shock at Nurmahal, it being said that the shock "did not cause any damage."

Sounds accompanying the shock.

Nothing of an interesting character has been received regarding the sounds accompanying the earthquake. A "thundering and creaking" sound was heard at Lahore; a sound "like a strong windstorm" at Gurais; and a "noise like that of an aeroplane" at Sonamarg. No special noises were heard by the other observers.

Variation in the number of shocks and their duration.

In the table given on page 281, it will be noted that there is so great a variation in the number of recorded shocks and their duration, due, doubtlessly, to inaccuracy of observation, that no useful purpose can be served by their study.

3. Instrumental Records.

Station from which records were received.

Instrumental records of this earthquake were obtained from the Meteorological Observatories at Colaba (Bombay), Alipore (Calcutta) and Kodaikanal (in the Madras Presidency). Unfortunately the seismographs at Simla were being transferred to Agra and so no record was available from them. A seismogram from an instru-

[1] *Op. cit.*, p. 27.

[2] This is all that was reported from Kargil.

ment situated at Simla would have greatly assisted in the determination of the epicentre of this earthquake. No record was available from the instrument situated at Rangoon.

Colaba.

The different phases of the shock, as recorded by the N.—S. horizontal component of the Milne-Shaw seismograph (period—12 seconds; damping ratio—20 : 1) in the Colaba Observatory, were given as under in Indian Standard Time:—

	Day.	Hour.	Minute.	Second.
P . . .	1	22	48	15
S . . .	1	22	50	31
L . . .	1	22	51	36
M . . .	1	22	56	50
F . . .	2	0	37	. .

P = Time of commencement of First Preliminary Tremors.
S = Time of commencement of Second Preliminary Tremors.
L = Time of commencement of Long Waves.
M = Time of Maximum Movement.
F = End of shock

The following are the corresponding times as recorded by the E.—W. horizontal component of the same seismograph:—

	Day.	Hour.	Minute.	Second.
P . . .	1	22	48	22
S . . .	1	22	50	37
L . . .	1	22	51	40
M . . .	1	22	52	0
F . . .		Lines congested.		

However, as the lines in this record were congested and the phases could only be made out with difficulty, the record of the N.—S. component has been taken as the true time record for Colaba[1].

The maximum amplitude was 76 microns (=·076 mm.). Owing to large and rapid oscillations, the lines in the photographic record were faint and were not suitable for preparing photographic copies.

[1] The first times received from the Colaba Observatory for the N.-S. horizontal component differed from those given above.

It may be easily deduced from these times that the rates of propagation of the long waves are as given in the following table, the results in Column A being obtained from the interval between Colaba and Alipore; those in Column B, from the interval between Colaba and Kodaikanal; and those in Column C from the interval between Alipore and Kodaikanal.

	A.	B.	C.
Interval . .	44 seconds.	222 seconds.	178 seconds.
Distance . .	245 km.	1,005 km.	760 km.
Velocity . .	5·6 km./sec.	4·5 km./sec.	4·3 km./sec.

When it is remembered that the usual rate obtained is 3·8 kilometres per second,[1] these figures, besides varying greatly in one instance, seem abnormally high. But these values were obtained on three assumptions, *viz.*, that the rate of propagation of the long waves throughout their paths was uniform; secondly, that the times given by the three observatories were accurate; and, lastly, that the position of the epicentre was that indicated by the observers' reports.

Rate of propagation in alluvium different from that in rock.

Consider the paths of the long waves to Colaba, Alipore and Kodaikanal. Of the 1,795 km. distance to Colaba from the presupposed epicentre, one may, perhaps, regard 815 km. to be loosely consolidated alluvium and 980 km. solid rock. Of the 2,040 km. to Alipore, there are only 625 km. of alluvium but 1,415 km. of rock. Similarly, we have approximately 710 km. of alluvium and 2,090 km. of rock on the path to Kodaikanal from our epicentre.[2] Let us assume that the long waves have a velocity of 3·8 km. per second in rock. Then, by considering the three time intervals between Colaba and Alipore, Colaba and Kodaikanal, and Alipore and Kodaikanal, it can easily be deduced that the velocities in the alluvial part of the paths which will give time intervals of 44, 222

[1] O. Klotz. *Bull. Seis. Soc. Amer.*, VII, 1907, pp. 67-71.

[2] These estimates were obtained from measurements on a map of scale 32 miles = 1 inch, due allowance being made for the curvature of the great circles passing through the epicentre and Colaba, Alipore and Kodaikanal, respectively. The effect of the great circles is negligible for the paths of the waves proceeding from the epicentre to Colaba and to Kodaikanal; but there is an approximate increase of 50 kilometres of alluvium in the great circle path from the epicentre to Alipore when compared with the straight line estimate. The great circle path of the wave proceeding to Alipore still lies to the north of Simla.

and 178 seconds must be 2·7, 1·5 and 231 km.[1] per second respectively.

These figures vary greatly; but if the figures obtained from Kodaikanal times be neglected, *i.e.*, 1·5 and 231, it is suggested that it is not unreasonable to consider a velocity of 2·7 km. per second for the long waves through alluvium as being probable. It has already been mentioned that the times of Kodaikanal records are not always correct, inasmuch as the instrument in use there is of an old type and is not very sensitive.

Additional support to the view that there is an inaccuracy in at least one of the instrumental records is given by the impossible position of the epicentre when determined by the usual methods. If, for instance, we assume that the long waves have a uniform velocity of 3·8 km. per second and draw circles on a map around Alipore and Kodaikanal with radii of 167 km. and 844 km. respectively, corresponding to time intervals of 44 and 222 seconds, the centre of the circle passing through Colaba and cutting these two circles tangentially, *i.e.*, the epicentre, will be found to be near Dholpur[2].

Determination of the epicentre from the instrumental records.

Again, determination of the position of the epicentre by Omori's method,[3] by Zeissig's method[4] and by Galitzin's method[5] give equally impossible positions for the epicentre.

There is no possibility that the records of a "sympathetic" shock[6] from Central India have been superimposed on the records of all three stations to the obliteration of the records of the Northern Indian earthquake.

[1] A slight variation in the relative amounts of alluvium and rock in the path of the wave from the epicentre to Alipore makes a large difference in the value obtained for the velocity in alluvium by comparison with the Alipore and Kodaikanal times. Thus, if there were 585 km. of alluvium and 1,455 km. of rock, the velocity in alluvium would be 11·6 km. per second. The corresponding effect on the velocity as determined by comparison of the Colaba and Alipore times, is small.

[2] It is considered unnecessary to use a globe for distances of this magnitude; were one used, a slight difference in position would doubtlessly be obtained.

[3] E. Omori. *Bull. Imp. Earth. Inv. Comm.*, IX, No. 1 1918, pp. 33-39. Omori states (p. 38) that his equation "may possibly be extended" to distances of 2,000 km.

[4] C. Davison. A Manual of Seismology, Cambridge, 1921, p. 159.

[5] B. Galitzin. *Compt. Rend. Acad. Sci. Paris*, CL, 1910, pp. 642-45, 816-19 *Nature*, XC, 1912, p. 3.

[6] *Cf.* Stuart, *op. cit.*, pp. 48-52.

Conclusions.

Accordingly, provided that the times given for instruments at Colaba and Alipore have been correctly recorded, one must conclude :—

1. That the times given for the instrument at Kodaikanal have been incorrectly recorded.

2. That, assuming the velocity of the long waves varies according to whether the medium traversed be alluvium or rock, one can explain the difference in time (44 seconds) between the arrival of the long waves at Colaba and Alipore, though it is less by 20½ seconds than it should be (64½ seconds) if the long waves had a uniform velocity of 3·8 km. per second and if the position of the epicentre were as indicated by the observers' reports.

3. That the depth of the focus of this earthquake might be such that the usual rates of propagation of the long waves (and of the other waves) are inapplicable.

Regarding the second conclusion, it will be very interesting if, on the occasion of the next shock of considerable magnitude in the epicentral tract, the difference in time of arrival of the long waves at Colaba and at Alipore is observed. If this be of the same order, *i.e.*, less than what one might expect if the long waves had a uniform velocity of 3·8 km. per second, then additional support will be given to the assumption that the long waves have a different velocity in alluvium from that in rock.

5. Earlier Shocks and Aftershocks.

It has already been stated that the epicentral area is very unstable. This is also shown by the following table which gives the dates of the shocks felt in this area during the twelve months immediately preceding the shock of the 1st February, 1929, and the stations where they were observed.

Instability of the epicentral area.

Date.	Stations.
21st January 1928	Srinagar, Drosh and Cherat.
19th February 1928	Drosh.
25th February 1928	Srinagar, Drosh and Cherat.
12th April 1928	Drosh.
13th April 1928	Drosh.
25th April 1928	Srinagar.
2nd May 1928	Drosh.

Date.	Stations.
3rd May 1928 . . .	Drosh (three different shocks).
14th June 1928 . .	Drosh.
24th June 1928 . .	Srinagar and Drosh.
10th July 1928 . .	Srinagar.
10th August 1928 . .	Drosh, Peshawar and Skardo.
10th August 1928 . .	Srinagar and Gulmarg (different from above).
14th November 1928 .	Srinagar, Drosh and Gurais.
3rd December 1928 . .	Drosh.
7th December 1928 . .	Drosh.
14th December 1928 .	Drosh.
14th January 1929 . .	Srinagar.

The only shock which has occurred after the earthquake under investigation, was felt at Gurais and Srinagar on the 13th March, 1929.

MISCELLANEOUS NOTES.

Indian Beryl.

In the "Chemical Trade Journal and Chemical Engineer" of September 28th, 1928, Kurt Illig, of the Siemens-Halske A.-G., Berlin, Germany, gives a *résumé* of a paper on beryllium metal presented by him before the American Electrochemical Society.[1]

The metal beryllium is produced from the mineral beryl, which contains from 3-4 per cent. of beryllium, by a fused electrolyte process; it is an extremely light (S. G.-1·8), hard, and brittle metal which scratches glass and can neither be rolled nor drawn because of its coarse crystalline structure. The addition of from 2-2·5 per cent. of beryllium to copper or nickel produces alloys possessing properties like those of the bronzes, but the most outstanding property of the beryllium alloys is in their improvement on heat treatment.

About 60 per cent. of the beryllium content is recoverable from crude beryl so that 500 kg. of the mineral is required to produce 1 kg. of the metal. The prices for the raw beryl are extremely high and in September 1928 it was costing from 150 to 200 dollars per metric ton, whilst the lowest bids for large amounts of the mineral varied between 60 and 70 dollars, *i.e.*, 167 and 195 rupees per ton. It certainly appears, therefore, as though the Indian occurrences of beryl might be worth attention. A note of warning must however be sounded. The investigations of the properties of the metal are as yet only in their infancy and the prices that have been paid for raw beryl, the source of the metal, are probably due to the fact that as yet no adequate marketing facilities are in existence.

In India beryl occurs as an accessory mineral in the coarse mica pegmatites of Bihar and Orissa, Nellore and Kishengarh, but up to the present the large, much-fissured crystals of the pale-coloured varieties, some of them a foot or more in length and from 6 to 8 inches in diameter, which are found close to the mica books on the outside flanks of the quartz cores of the pegmatites, have only been collected for the included clear fragments which might be cut as aquamarines.

It is difficult to estimate what the annual production of beryl in India might be from the mica pegmatites which are being actively worked in Bihar and Orissa and Nellore, but my colleagues Dr. C. S. Fox and Mr. G. V. Hobson estimate an annual production of from 3-4 tons from the Kodarma Forest Area in Bihar and Orissa and 5 tons from the mica belt in Nellore. These estimates would probably be greatly exceeded in the first year or two. Dr. Heron informs me that several tons of weathered-out beryl could be collected from the slopes of the hills which run north from Ajmere to Narwar in Kishengarh.

[1] *Trans* 54.

As organisations are in existence for the collection of mica, it may be worth while drawing their attention to a possible use of beryl which is at present a waste product.

E. L. G. CLEGG.

An occurrence of Atacamite in Bihar.

A small specimen of atacamite, the oxychloride of copper, from the Palamau district of Bihar, was forwarded to this Department for identification by Mr. A. F. Newell, of Calcutta. This mineral, registered as N-86, was exhibited at the Annual Meeting of the Asiatic Society of Bengal held at Calcutta on the 4th February, 1929. Atacamite has been previously recorded in India from Garimanipenta, in the Nellore district.[1]

A. L. COULSON.

Pyromorphite in the Bhagalpur district, Bihar.

A small specimen of pyromorphite, now No. N-87 in the mineral collections of this Department, was forwarded for identification by Mr. T. Chowdry, of Jamtara, Bihar. The mineral is said to occur at Chandun (? 24° 37′ : 86° 40′) in the Bhagalpur district of Bihar, in which district lead ores have long been known to exist.[2] Pyromorphite has previously been recorded in India from the Feudatory States of the Central Provinces [3] and doubtfully from Burma.[4]

A. L. COULSON.

[1] F. R. Mallet, *Rec. Geol. Surv. Ind.*, XII, p. 171.

[2] V. Ball. Manual of the Geology of India, Pt. III, Economic Geology, Calcutta, 1881, p. 289.

[3] *Rec. Geol. Surv. Ind.*, LXII, Pt. I, 1929, p. 13.

[4] F. R. Mallet. Manual of the Geology of India, Pt. IV, Mineralogy, Calcutta, 1887, pp. 132, 133.

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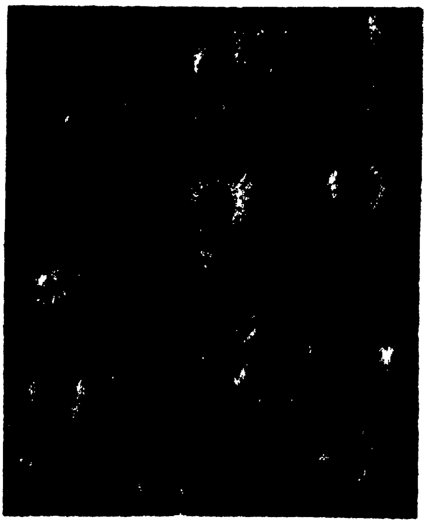

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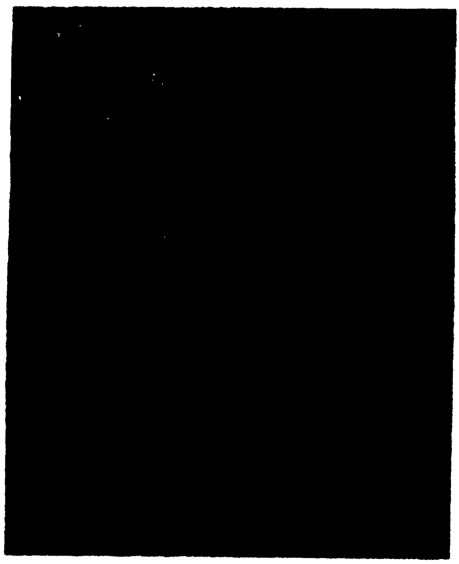

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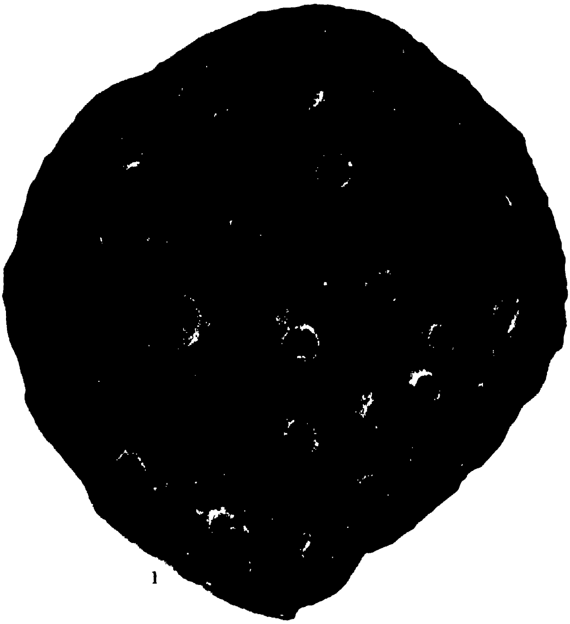
W. Tams, phot.

DEVONIAN FOSSILS FROM BURMA



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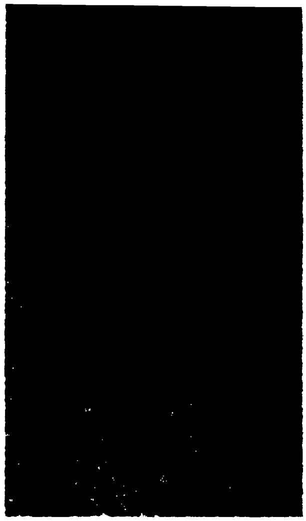

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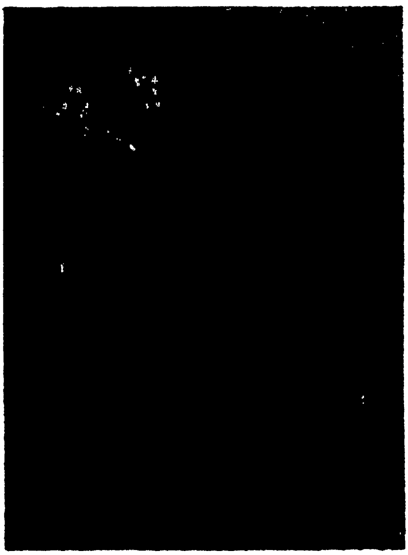

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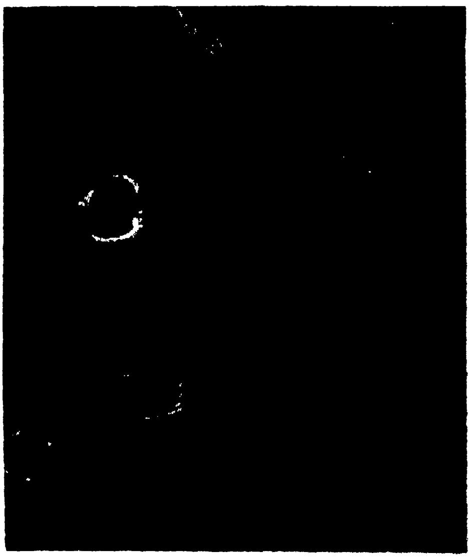

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W. Tams, phot.

DEVONIAN FOSSILS FROM BURMA

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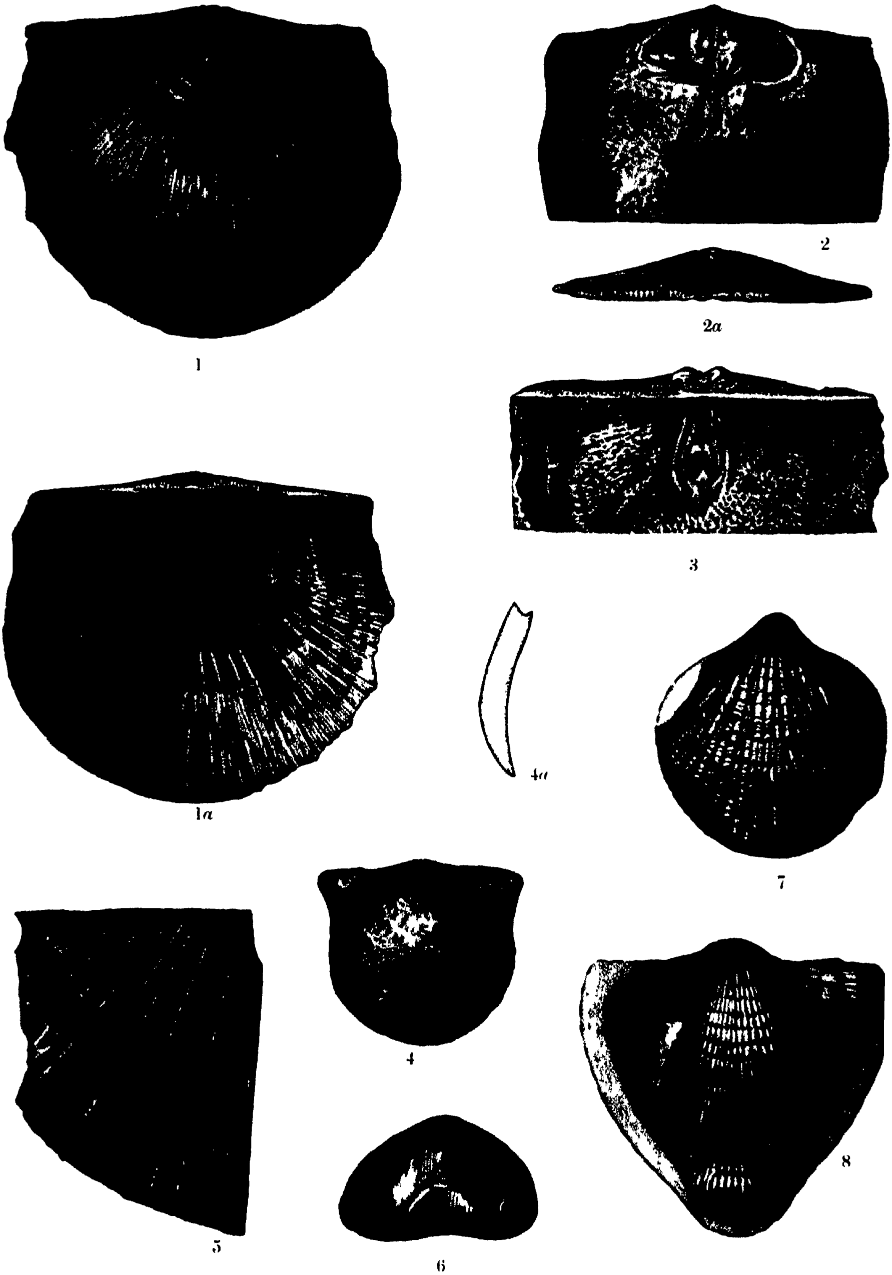

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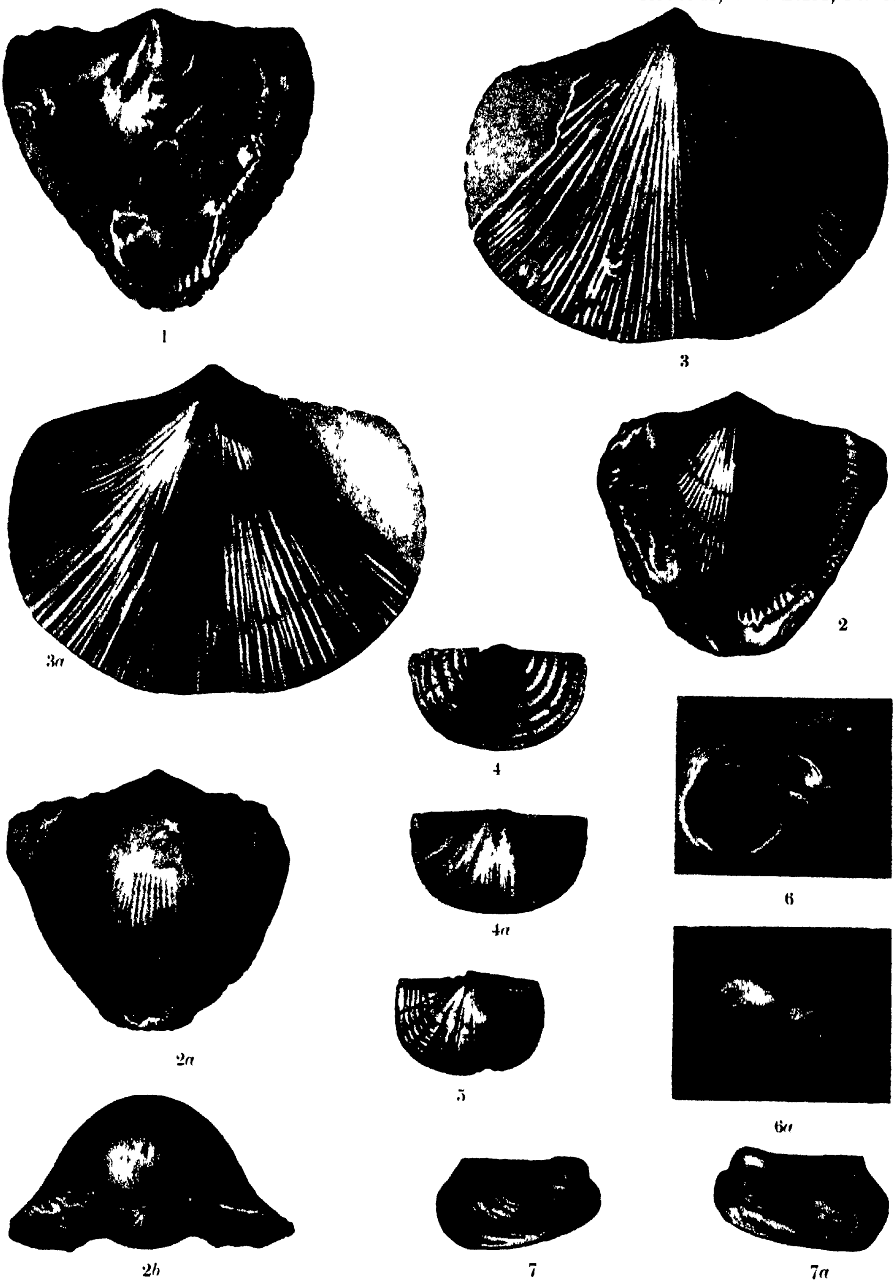

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DEVONIAN FOSSILS FROM BURMA

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1929. [September.

THE MINERAL PRODUCTION OF INDIA DURING 1928. BY SIR EDWIN PASCOE, M.A., SC.D. (CANTAB.), D.SC. (LOND.), F.G.S., F.A.S.B., *Director, Geological Survey of India.*

CONTENTS.

INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these Records (Vol. XXXII, 1905), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. As the methods of collecting

the returns become more precise, and the machinery employed for the purpose more efficient, the number of minerals included in Class I—for which approximately trustworthy annual returns are available—increases, and it is hoped that the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will in time be reduced to a very small number. In the case of minerals still exploited chiefly by primitive Indian methods, and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible; the total error from year to year, however, is characterised by some degree of constancy, and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small indigenous alluvial industry contributes such an insignificant portion to the total outturn that the error from this source may be regarded as negligible.

The average value of the Indian rupee during the year 1928 was 1*s.* $5\frac{31}{32}$*d.*; the highest value reached was 1*s.* $6\frac{3}{32}$*d.* and the lowest 1*s.* $5\frac{27}{32}$*d.* The values for 1928 shown in the tables are given on the basis of 1*s.* $5\frac{31}{32}$*d.* to the rupee; for ease of calculation, £1 has been taken to be equivalent to Rs. 13·4, instead of Rs. 13·36.

Table 1 shows the total value of minerals for which returns of production are available for the years 1927 and 1928. The average figure for the quinquennium, 1919-23, was £24,615,727. In the following year, 1924, there was an apparent increase of over £3,600,000; this was, in part, however, due to the higher average value of the rupee during that year. Since 1924, there has been a steady decline which has persisted down to the year under review. 1928 shows a decrease in total value amounting to a little under £900,000 or about 3·9 per cent. of the value of the total production over that of 1927. This decrease is minimised by a slight increase in the average exchange value of the rupee. An increase or decrease in value does not always correspond to a similar variation in output, and cannot, therefore, be regarded as an infallible indication of the state of an industry. It must be understood that the figures of Table 1 are value figures, and that a decrease does not necessarily mean a reduced output or a decline in the industry. For instance, in the cases of coal, lead and lead-ore, magnesite and mica, an increase in production accompanied the decrease in value, the latter being due chiefly to a drop in the market price. Nearly 9

TABLE 1.—*Total Value of Minerals for which returns of production are available for the years 1927 and 1928.*

——	1927 (£1= Rs. 13·4).	1928 (£1= Rs. 13·4).	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	7,079,852	6,604,106	..	475,746	—6·7
Petroleum	4,421,468	4,314,207	..	107,261	—2·4
Manganese (*a*)	2,844,237	2,321,201	..	523,036	—18·4
Lead and Lead ore (*b*)	1,641,095	1,642,036	941	..	+0·1
Gold	1,626,913	1,588,252	..	38,661	—2·4
Building materials	914,187	1,110,907	196,720	..	+21·5
Silver	708,846	892,460	183,614	..	+25·9
Salt	849,265	745,899	..	103,366	—12·1
Mica (*c*)	691,341	698,130	6,789	..	+1·0
Zinc-ore (*c*)	522,737	553,051	30,314	..	+5·8
Iron-ore	380,735	413,058	32,323	..	+8·5
Copper-ore and matte	344,299	399,150	54,851	..	+15·9
Tin-ore	493,864	338,895	..	154,969	—31·3
Saltpetre (*c*)	113,632	74,629	..	39,003	—34·3
Chromite	65,743	57,139	..	8,604	—13·1
Jadeite (*d*)	22,570	43,468	20,898	..	+92·6
Ilmenite	33,443	41,557	8,114	..	+24·2
Nickel speiss	13,176	39,922	26,746	..	+203·0
Clays	19,819	31,655	11,836	..	+59·7
Antimonial lead	9,930	23,658	13,728	..	+138·2
Tungsten-ore	42,537	22,354	..	20,183	—47·4
Ruby, sapphire and spinel.	20,883	13,247	..	7,636	—36·5
Magnesite	17,115	11,969	..	5,146	—30·1
Gypsum	6,702	10,919	4,217	..	+62·0
Steatite	7,816	9,706	1,890	..	+24·2
Bauxite	2,107	7,034	4,927	..	+233·8
Refractory materials	5,803	6,360	557	..	+9·6
Zircon	8,129	4,267	..	3,862	—47·5
Ochre	2,051	3,953	1,902	..	+92·7
Diamonds	3,354	3,875	521	..	+15·5
Fuller's earth	1,687	1,852	165	..	+9·8
Asbestos	1,011	1,622	611	..	+60·4
Barytes	738	1,463	725	..	+98·2
Monazite	3,810	1,242	..	2,568	—67·4
Apatite	750	1,081	331	..	+44·1
Amber	2,028	897	..	1,131	—55·7
Antimony-ore	784	769	..	15	—1·9
Alum	1,728	412	..	1,316	—76·2
Corundum	598	207	..	391	—65·4
Garnet	53	90	37	..	+69·8
Soda	34	44	10	..	+29·4
Bismuth	10	20	10	..	+100·0
Serpentine	..	6	6	..	..
Borax	1	2	1	..	+100·0
Copperas	1	1	.	..	..
TOTAL	22,926,882	22,036,772	602,784	1,492,894	—3·9
			—890,110		

(*a*) Export f.o.b. value.
(*b*) Excludes the value of antimonial lead.
(*c*) Export values.
(*d*) Export values for 1927-28 and 1928-29.

per cent. of the decrease in total value of all minerals was, however, due to a marked fall in the value of the petroleum output in spite of a large increase in the output itself; this was the result of a rate-war with outside rivals.

The number of mineral concessions granted during the year under review amounted to 497, against 714 in the preceding year. Of these, 396 were prospecting licenses and 101 were mining leases. As India becomes more and more thoroughly explored, the number of new mineral concessions taken up annually must necessarily decrease, but the enormous drop reported in the present case seems to indicate a regrettable decline in prospecting and private geological enterprise in the country.

II.—MINERALS OF GROUP I.

Antimony.

The production of antimonial lead obtained as a by-product in the lead refinery at the Namtu smelter of the Burma Corporation, Limited, increased from 503 tons valued at Rs. 1,33,065 (£9,930) in 1927 to 1,241 tons valued at Rs. 3,17,011 (£23,658) in 1928. This product contains approximately 77 per cent. of lead, 21 per cent. of antimony and from 6 to 8 oz. of silver to the ton, and is exported to the United States of America for further treatment.

A small quantity of antimony ore is also produced in the Amherst district, Burma. The output in 1928 amounted to 370 tons valued at Rs. 10,300 (£769) against 500 tons valued at Rs. 10,500 (£784) in the previous year.

Chromite.

There was a decrease in the production of chromite in India during 1928, amounting to 11,752 tons. The deposits in the Mysore State were chiefly responsible for this decrease. The total exports from India during the year were almost equal to the production, amounting to 45,308 tons. Chromite exported from the ports in British India amounted to 31,209 tons against 20,996 tons in 1927. Chromite mined in British India is also exported from the port of Mormugao in Portuguese India; the quantities exported from that port during 1927 and 1928 were 21,957 tons and 14,099 tons respectively. Although the production decreased, the value per ton rose to Rs. 16·8 from Rs. 15·4 in 1927.

Something like half the world's supplies of chromite come from Southern Rhodesia which has now become the predominant source of this mineral.

TABLE 2.—*Quantity and Value of Chromite produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Baluchistan—						
Zhob . .	14,534	2,18,014	16,270	15,002	2,25,030	16,793
Bihar & Orissa—						
Singhbhum .	2,552	49,431	3,689	2,165	48,949	3,653
Mysore State—						
Hassan .	34,030	4,88,076	36,423	23,639	3,86,008	28,806
Mysore .	6,091	1,25,436	9,361	4,649	1,05,681	7,887
TOTAL .	**57,207**	*8,80,957*	*65,743*	**45,455**	*7,65,668*	*57,139*

Coal.

There was an increase during the year of 460,500 tons, or about 2·08 per cent., in the output of coal. This increase was due chiefly to Bihar and Orissa, partly to Bengal and the Central Provinces, and, to a decreasing extent, to Hyderabad, Rajputana, Baluchistan and Central India. There was a decrease in the production of Assam and the Punjab. The increase in Bihar and Orissa was mostly from Bokaro, Karanpura and Jharia. Bokaro now produces 9 per cent. of the Indian total. Giridih decreased her raisings by over 51,000 tons. Karanpura, on the other hand, made another stride from 262,014 tons in 1927 to 390,493 tons in 1928. Jharia showed another small proportionate increase of some 82,000 tons, but was still below her figure for 1925. Talchir continued its upward movement with an increase of nearly 15,000 tons. There was a slight recovery on the part of Rampur, which was more than set off by the decline in the case of Jainti. The Raniganj field showed a proportionately small decline of over 11,500 tons. In Central India there was a marked increase in the output from Sohagpur, which was more or less balanced by a decrease in the case of Umaria. In the Central Provinces there was another substantial increase in the output from the Pench Valley, and also from Ballarpur. In Hyderabad,

both the Singareni and Sasti fields were responsible for appreciable increases.

The statistical position at the end of the year showed a continued improvement in spite of the increase in the total output. Stocks in the six provinces of Assam, Baluchistan, Bengal, Bihar and Orissa, the Central Provinces, and the Punjab, for which such figures are available, showed a total reduction of 95,571 tons, as is seen from the following data :—

Year.	Opening stock.	Closing stock.	Reduction during year.
	Tons.	Tons.	Tons.
1927	2,161,806	1,721,288	440,518
1928	1,721,288	1,625,717	95,571

In spite of the increased output, the total value of the coal produced in India decreased from Rs. 9,48,70,013 (£7,079,852) in 1927 to Rs. 8,84,95,027 (£6,604,106) in 1928.

There was again a reduction in the pit's mouth value per ton of coal for India as a whole from Rs. 4-4-9 to Rs. 3-14-10—a fall of Re. 0-5-11—and all provinces participated in this fall with the exception of Assam and Baluchistan, the rise in the case of Assam being 7 pies only. In the two great coal provinces, Bihar and Orissa and Bengal, the value dropped by Re. 0-5-5 and Re. 0-7-4 respectively. In the Central Provinces it fell by Re. 0-3-3; in Central India the fall was Re. 0-8-3, and in the Punjab Re. 0-6-10.

TABLE 3.—*Provincial production of Coal during the years 1927 and 1928.*

Province.	1927.	1928.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	323,342	298,089	..	25,253
Baluchistan	14,444	17,931	3,487	..
Bengal	5,554,990	5,639,993	85,003	..
Bihar and Orissa . . .	14,517,866	14,827,453	309,587	..
Central India . . .	217,661	218,750	1,089	..
Central Provinces . . .	666,758	732,353	65,595	..
Hyderabad	707,213	734,765	27,552	..
Punjab	62,704	46,152	..	16,552
Rajputana	17,358	27,386	10,028	..
Total .	***22,082,336***	***22,542,872***	***502,341***	***41,805***

TABLE 4.—*Value of Coal produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Value (£1 = Rs. 13·4).		Value per ton.	Value (£1 = Rs. 13·4).		Value per ton.
	Rs.	£	Rs. A. P.	Rs.	£	Rs. A. P.
Assam	41,13,400	306,970	12 11 7	38,04,662	283,930	12 12 2
Baluchistan . . .	1,21,255	9,049	8 6 4	1,63,959	12,236	9 2 4
Bengal	2,46,54,598	1,839,895	4 7 0	2,24,34,052	1,674,183	3 15 8
Bihar and Orissa . .	5,79,61,693	4,325,500	3 15 11	5,42,11,122	4,045,606	3 10 6
Central India . .	9,55,849	71,332	4 6 3	8,47,939	63,279	3 14 0
Central Provinces . .	29,40,268	219,423	4 6 7	30,81,627	229,972	4 3 4
Hyderabad (*a*) . .	35,54,461	265,258	5 0 5	34,55,648	257,884	4 11 3
Punjab	4,48,791	33,492	7 2 6	3,10,448	23,168	6 11 8
Rajputana . . .	1,19,698	8,933	6 14 4	1,85,570	13,848	6 12 5
Total .	**9,48,70,013**	**7,079,852**	..	**8,84,95,027**	**6,604,106**	..
Average .	..	..	*4 4 9*	..	..	*3 14 10*

(*a*) Estimated.

TABLE 5.—*Origin of Indian Coal raised during the years 1927 and 1928.*

—	Average of last five years.	1927.	1928.
	Tons.	Tons.	Tons.
Gondwana Coalfields	20,522,285	21,664 488	22,153,314
Tertiary Coalfields	441,589	417,848	389,558
Total .	**20,963,874**	**22,082,336**	**22,542,872**

TABLE 6.—*Output of Gondwana Coalfields for the years 1927 and 1928.*

—	1927.		1928.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Bengal, Bihar and Orissa—				
Bokaro	1,790,594	8·11	2,026,791	8·99
Daltonganj	..	..	929	0·01
Giridih	855,253	3·87	804,118	3·57
Hutar	709	..	205	..
Jainti	56,724	0·26	48,059	0·21
Jharia	10,583,487	47·93	10,665,479	47·31
Karanpura	262,014	1·19	390,493	1·73
Rajmahal Hills . . .	1,488	0·01	636	..
Ramgarh	340	..	386	..
Rampur (Raigarh-Hingir) .	26,895	0·12	31.623	0·14
Raniganj	6,472,036	29·31	6,460,490	28·66
Talchir	23,316	0·10	38,237	0·17
Central India—				
Sohagpur	82,541	0·37	117,423	0·52
Umaria	135,120	0·61	101,327	0·45
Central Provinces—				
Ballarpur	158,617	0·72	175,872	0·78
Pench Valley	505,913	2·29	556,481	2·47
Shahpur	6	..	..	..
Yeotmal	2,222	0·01	..	..
Hyderabad—				
Sasti	25,477	0·12	35,615	0·16
Singareni	681,736	3·09	699,150	3·10
Total .	21,664,488	*98·11*	22,153,314	*98·27*

TABLE 7.—*Output of Tertiary Coalfields for the years 1927 and 1928.*

—	1927.		1928.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Assam—				
Khasi and Jaintia Hills .	825		588	
Makum	271,220	1·46	238,926	1·32
Naga Hills	51,297		58,575	
Baluchistan—				
Khost	1,734	0·07	2,542	0·08
Sor Range, Mach, Kalat .	12,710		15,389	
Punjab—				
Jhelum	39,545		24,674	
Mianwali	15,488	0·28	18,161	0·21
Shahpur	7,671		3,317	
Rajputana—				
Bikanir	17,358	0·08	27,386	0·12
Total .	417,848	*1·89*	389,558	*1·73*

The export statistics for coal during 1928 show a notable increase of over 49,000 tons, which more than balances the decrease of the previous year which amounted to some 43,000 tons, the total exports of coal and coke rising from 576,167 tons to 626,343 tons, 3,473 tons of the latter being coke (*see* Table 8). The increase in exports is due chiefly to Hongkong which absorbed some 110,700 tons. As before, the major portion of the exports went to Ceylon, which took nearly 11,000 tons more than during the previous year. The Philippine Islands and Guam also took a considerably larger quantity than they did in 1927. Exports to the Straits Settlements (including Labuan), on the other hand, were less than half of what they were in the preceding year. Other countries absorbed nearly 14,000 tons less.

TABLE 8.—*Exports of Indian Coal and Coke during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
To—	Tons.	Rs.	£	Tons.	Rs.	£
Ceylon	340,546	44,73,416	333,837	351,496	42,65,166	318,296
Hongkong	..	..	..	110,701	13,43,907	100,292
Philippine Islands and Guam.	56,052	4,85,349	36,220	72,089	5,83,546	43,548
Straits Settlements (including Labuan).	145,933	16,06,709	119,904	71,040	7,77,565	58,027
Other countries	31,302	3,58,446	26,750	17,544	2,07,818	15,509
TOTAL	573,833	69,23,920	516,711	622,870	71,78,002	535,672
Coke	2,334	52,193	3,895	3,473	69,595	5,193
Total of coal and coke	576,167	*69,76,113*	*520,606*	626,343	*72,47,597*	*540,865*

These increased export figures are, however, still below those of some earlier years (for example, 1,224,758 tons in 1920). As they are partly the result of the first two or three years' operations of the Indian Coal Grading Board, established for the purpose of certifying the quality of coal exported from the port of Calcutta, they are, on the whole, a favourable augury for the future prospects of this scheme for the rehabilitation of Indian coal in foreign markets. The following table shows the amounts of different grades of coal exported during 1927 and 1928 under the above scheme (including sea-borne coal for railways in Southern India, for which no grade shipment certificates were issued by the Coal Grading Board), the

difference between the total amounts so exported (2,308,342 tons in 1928) and the total exports of Indian coal to foreign ports given in Table 8 (622,870 tons in 1928) being the amount of coal exported to Indian ports.

Table 9.—*Exports of Coal under Grading Board Certificates during the years 1927 and 1928.*

—	1927.	1928.
	Tons.	Tons.
Selected grade	1,733,880	1,836,253
Grade I	373,632	422,628
Grade II	22,068	3,926
Grade III	4,054	..
Mixed grades	80,935	43,580
Under reference	9,604	1,955
Total	2,224,173	2,308,342

Imports of coal and coke fell from 243,603 tons in 1927 to 210,186 tons in 1928; 21,970 tons of the latter consisted of coke (*see* Table 10). This decrease is due chiefly to a fall of nearly 19,000 tons in the imports from South Africa. There was a decrease also of some 15,800 tons from the United Kingdom, about 5,700 tons less from Australia, and nearly 10,000 tons less from other countries, excluding Portuguese East Africa imports from which increased by some 2,300 tons. The total imports are now less than half those of the pre-war quinquennium and Table 11, comparing pre-war imports and exports with the 1927 and 1928 figures, shews that the depression in the Indian coal industry which continued till nearly the end of 1928, can no longer be looked upon as attributable to the competitive effect of foreign imported coal. The average surplus of exports over imports during 1927-28 was, in fact, greater than the surplus during the pre-war quinquennium.

TABLE 10.—*Imports of Coal and Coke during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
From—	Tons.	Rs.	£	Tons.	Rs.	£
Australia	11,017	2,94,405	21,971	5,321	1,16,178	8,670
Portuguese East Africa.	29,314	6,74,391	50,328	31,577	5,80,836	43,346
Union of South Africa	132,357	28,67,969	214,027	113,431	22,14,144	165,235
United Kingdom	50,209	13,26,362	98,982	34,419	8,12,021	60,599
Other countries	13,395	2,99,360	22,340	3,468	56,849	4,242
TOTAL	236,292	54,62,487	407,648	188,216	37,80,028	282,092
Coke	7,311	2,90,262	21,661	21,970	6,82,096	50,902
Total of Coal and Coke	243,603	*57,52,749*	*429,309*	210,186	*44,62,124*	*332,994*

TABLE 11.—*Excess of Exports over Imports of Coal.*

—	Exports.	Imports.	Excess of exports over imports.
	Tons	Tons.	Tons.
Average for 1909-13	814,475	466,162	348,313
1927	576,167	243,603	332,564
1928	626,343	210,186	416,157

The average number of persons employed in the coalfields during the year showed a slight decrease in spite of the substantial increase in production. The average output per person employed, therefore, again showed an advance on the previous years, the figure of 110·5 tons for 1925 rising to 113·1 tons for 1926, 122·3 tons for 1927 and 125·5 tons for 1928. The figure for the year under review is higher than any previously recorded, and is the result, partly of an increased use of mechanical coal-cutters and partly to concentration of work. During the past few years a large number of collieries have been shut down and the labour absorbed in the remainder; this concentration permits of a proportional reduction in the supervising staff, resulting in a larger tonnage per head. There was a regrettable increase in the number of deaths by accident; these amounted to 234, which is, nevertheless, still an improvement on the annual average for the quinquennium 1919-23, which was 274. In addition, it relates to a production which is over $2\frac{3}{4}$ million tons in excess of the average for 1919-23. The death rate was 1·3 per thousand persons employed in 1928, against 1·1 for 1927; the average figure for the period 1919-23 was 1·36.

TABLE 12.—*Average number of persons employed daily in the Indian Coalfields during the years 1927 and 1928.*

—	Number of persons employed daily.		Output per person employed, in tons.	Number of deaths by accident.	Death rate per 1,000 persons employed.
	1927.	1928.			
Assam	4,034	4,216	70·7	7	1·7
Baluchistan	323	254	70·6	..	..
Bengal	44,274	43,855	128·6	64	1·5
Bihar and Orissa	109,196	108,546	136·6	136	1·3
Central India	3,259	3,144	69·6	2	0·6
Central Provinces	6,553	6,923	105·8	10	1·4
Hyderabad	11,464	11,816	62·2	13	1·1
Punjab	1,260	766	60·2	1	1·3
Rajputana	169	167	164·0	1	6·0
TOTAL	180,532	179,687	..	*234*	..
Average	..	..	*125·5*	..	*1·3*

Cobalt (see Nickel).

Copper.

Work at the Mosaboni Mine of the Indian Copper Corporation, Ltd., in the Singhbhum district, had been practically suspended during the year 1926, pending the raising of capital required for the erection of concentrating, smelting, refinery and power plants. Early in 1927, the Anglo-Oriental and General Investment Trust, Ltd., London, assumed control. A sum of £350,000 was subscribed and the erection of the new plant was commenced at the company's new site at Maubhandar, Ghatsila, together with an assisted siding from the Bengal-Nagpur Railway main line at Ghatsila, and an aerial ropeway from the mine.

During the greater part of the year 1928, development was confined to the blocking out of known ore bodies in preparation for stoping, and the completion of the main shaft for hoisting from the fifth, "No. 3. Inter." and second levels. The older pumps were replaced by electrically driven centrifugal pumps. The place of all the old steam-driven equipment has now been taken by the following:—two electrical compressors, each of a thousand cubic feet capacity; one electrical hoist (50 tons per hour); one electri-

cally driven, primary crushing plant with a capacity of 50 tons per hour; one belt conveyor delivering crushed ore to the ropeway bins; and one aerial ropeway, $5\frac{1}{2}$ miles in length, delivering ore to the reduction works at Maubhandar.

The main shaft was sunk a further $60\frac{1}{2}$ feet and is now $632\frac{1}{2}$ feet below the surface. The surface and underground ore reserves now total 755,630 short tons of 3·78 per cent. ore, representing a content of 28,584·06 short tons of copper. Since last year, therefore, the estimate of the ore reserves has increased by 131,091 short tons. Stoping commenced at the end of the year on a small scale, and 4,715 short tons of ore were broken.

During the year, the erection of all the units of the new plant for the production of refined copper was completed at Maubhandar. The main items of this plant are as follows:—railway siding; aerial-ropeway unloading station and ore bins; aerial-ropeway driving station and tension race; flotation mill for concentrating ore; bedding bins; reverberatory smelting furnace, converters and refinery furnace; power house (1875 kilo-watt capacity); boiler house (3 water-tube boilers); pulverised coal plant; flux-crushing plant; water-pumping station; machine shop; and laboratory. The whole of this plant, together with the mine plant referred to above, was in active operation by the end of the year 1928.

The amount of ore produced by the company in 1928 was 18,055 tons, valued at Rs. 7,22,200 (£53,896).

There was a slight decrease in the production of copper matte at the Namtu smelting plant of the Burma Corporation Limited. The average assay of this matte yields about 41 per cent. of copper, 35 per cent. of lead and 70 oz. of silver to the ton. The production during 1927 was 11,872 tons valued at Rs. 44,13,205 (£329,344) averaging 40·3 per cent. of copper and during 1928, 10,978 tons valued at Rs. 46,26,403 (£345,254) averaging 39·6 per cent. of copper. The matte is exported to Hamburg for further treatment.

There was no production of copper ore in the Nellore District of the Madras Presidency. A small output of 5 tons of copper ore was reported from the Mysore State in 1928.

Diamonds.

The production of diamonds in Central India amounted to 112·74 carats valued at Rs. 44,943 (£3,354) in 1927. The production

for 1928 has not been reported from Panna State; the value of the total production was, however, Rs. 51,922 (£3,875) during the year.

Gold.

The arrest in the secular decline in the total Indian gold production which took place in 1927 was not repeated in 1928. This was due chiefly to a decrease of nearly 6,000 oz. from Mysore, and to the fact that the North Anantapur Gold Mine Co., Ltd., ceased operations in the Anantapur district of Madras in July 1927.

Of the five mines producing gold on the Kolar gold field, the Champion Reef and the Ooregum mines reached vertical depths of 6,732 feet and 6,573 feet, respectively, below field datum, on the 31st of December 1928. A gratifying feature of the developments in depth is the continuity of the reef and the opening up of large bodies of payable ore. The dip of the reef, however, is becoming much steeper and is almost vertical in the lower levels. The ore is not refractory and yields its gold to a simple combination of amalgamation and cyaniding; "all-sliming" is gradually becoming general. The rock temperatures at the above enormous depths are 122·4° Fah. and 118·4° Fah., respectively. Owing to the great depth of the mines and the high rock temperatures, the problem of ventilation has been an extremely difficult one. It has been solved to some extent by sinking deep vertical shafts and by an extensive use of large electrically-driven fans to help the main air currents. A large volume of air is constantly kept in circulation by these fans installed in convenient places in the main airways. The brick and concrete lined shafts and winzes which are coming more and more into vogue in deep-level mining in this field considerably assist the free movement and increase the circulation of the air by reduction in friction. The shafts themselves are cleaner and less liable to damage by rock-bursts. The latter, even with the improved and more rigid forms of support adopted in place of the usual timbering and waste-rock filling, are still a source of anxiety and at times cause considerable damage to underground workings.

The working population on the Kolar gold field at the end of 1928 was 18,939, of which 3,622 persons were employed on the Champion Reef mine and 4,127 on the Ooregum mine.

TABLE 13.—*Quantity and value of Gold produced in India during the years 1927 and 1928.*

—	1927. Quantity.	1927. Value (£1 = Rs. 13·4).		1928. Quantity.	1928. Value (£1 = Rs. 13·4).		Labour.
	oz.	Rs.	£	oz.	Rs.	£	
Bihar & Orissa—							
Singhbhum .	..	..	..	7·0	352	26	13
Burma—							
Katha . .	11·5	778	58	16·6	1,066	79	(*a*)
Upper Chindwin.	48·2	4,169	311	54·7	4,741	354	(*a*)
Kashmir . .	48·0	2,048	153	60·0	2,520	188	160
Madras—							
Anantapur (*b*)	2,395·0	1,37,320	10,248	..	..	..	..
Mysore (*b*) .	381,723·0	2,16,54,394	1,615,999	375,886·0	2,12,72,297	1 587,485	18,826
Punjab . .	42·5	1,645	123	34·0	1,369	102	41
United Provinces	4·3	275	21	4·5	240	18	15
TOTAL .	384,272·5	*2,18,00,629*	*1,626,913*	376,062·8	*2,12,82,585*	*1,588,252*	*19,055*

(*a*) Not available.
(*b*) Fine gold.

Ilmenite.

There was a further increase in the production of ilmenite in the Travancore State, which amounted to 25,307 tons valued at £41,557 in 1928 against 17,809 tons valued at £33,443 in 1927. This mineral is collected with the monazite sands and, up to a few years ago, was looked upon as a by-product of the monazite industry. The increasing demand for the titania in the ilmenite is causing a resuscitation of the monazite industry, which had been adversely affected by the increased use of electricity for lighting purposes.

Iron.

The production of iron ore in India is still steadily on the increase; India is now, in fact, the second largest producer in the British Empire, and yields place only to the United Kingdom. Her output is of course still dwarfed by the production in the United States (over 60 million tons) and France (over 40 million tons); her reserves of ore are, however, not much less than three-quarters of the estimated total in the United States, and there is every hope that India will in the early future take a much more important place among the world's producers of iron ore. In 1928 there was an increase in the Indian output over the previous year of 11·3 per cent. amounting to 209,246 tons. The figures shown against the Keonjhar and Mayurbhanj States in Table 14 represent the

production by the United Steel Corporation of Asia, Ltd., and the Tata Iron & Steel Co., Ltd., respectively. Of the total production of 1,131,746 tons shown against Singhbhum, 415,761 tons were produced by the Tata Iron & Steel Co., Ltd., from their Noamundi mine, 380,605 tons by the Bengal Iron Co., Ltd., from their Pansira, Ajita and Maclellan mines, and 321,730 tons by the Indian Iron & Steel Co., Ltd., from their mines at Gua; the remaining 13,650 tons were produced by another firm. The output of iron ore in Burma is by the Burma Corporation Limited and is used as a flux in lead smelting.

TABLE 14.—*Quantity and value of Iron ore produced in India during the years 1927 and 1928.*

—	1927. Quantity.	1927. Value (£1 = Rs. 13·4).		1928. Quantity.	1928. Value (£1 = Rs. 13·4).	
	Tons.	Rs. (a)	£	Tons.	Rs. (a)	£
Bihar and Orissa—						
Keonjhar	36,325	1,08,975	8,132	141,361	4,24,083	31,648
Mayurbhanj	692,137	20,76,411	154,956	683,493	20,50,479	153,021
Sambalpur	561	3,930	293	21	265	20
Singhbhum	1,007,037	25,34,346	189,130	1,131,746	26,98,120	201,352
Burma—						
Mandalay	..	..	..	559	(a) 2,236	167
Northern Shan States	(a) 61,062	2,44,248	18,228	74,254	(a) 2,97,016	22,165
Central India	230	1,410	105	..	..	..
Central Provinces	918	3,846	287	923	3,939	294
Mysore	48,465	1,28,695	9,604	23,624	58,841	4,391
TOTAL	1,846,735	*51,01,861*	*380,735*	*2,055,981*	*55,34,979*	*413,058*

(a) Estimated.

There was a fall in the output of iron and steel by the Tata Iron & Steel Co. at Jamshedpur. The production of pig iron and steel (including steel rails) fell respectively from 624,028 tons and 414,738 tons in 1927 to 510,884 tons and 289,865 tons in 1928, and of ferro-manganese from 5,092 tons in 1927 to 3,233 tons in 1928. The production of pig iron by the Bengal Iron Co. fell from 132,649 tons in 1927 to 128,112 tons in 1928; their output of products made from their pig iron in 1928 amounted to 20,282 tons of sleepers and chairs and 27,180 tons of pipes and other castings, against 61,494 tons and 26,431 tons, respectively, in 1927. The Indian Iron and Steel Co. increased their production of pig iron from 363,516 tons in 1927 to 397,784 tons in 1928. The output of pig iron by the Mysore Iron Works fell from 19,858 tons in 1927 to 15,104 tons in 1928.

The total number of indigenous furnaces that were at work in the Central Provinces during the year 1928 for the purpose of smelting iron ore was 190 against 205 in the previous year; 102 furnaces were operating in the Bilaspur district, 54 in Mandla, 16 in Drug, 14 in Raipur, 3 in Saugor and 1 in Jubbulpore.

Although the production of pig iron in India decreased from 1,140,051 tons in 1927 to 1,051,884 tons in 1928, the quantity exported rose from 383,960 tons in 1927 to 428,625 tons in 1928. Table 15 will show that Japan is still the principal consumer of Indian pig iron, nearly 75 per cent. of the total exports having gone to that country in 1928. There was a further rise in the export value per ton of pig iron from Rs. 45·4 (£3·39) in 1927 to Rs. 47·0 (£3·51) in 1928.

The Steel Industry (Protection) Act, 1924—Act No. XIV of 1924—authorised, to companies employing Indians, bounties upon rails and fishplates wholly manufactured in British India from material wholly or mainly produced from Indian iron ore and complying with specifications approved by the Railway Board, and upon iron or steel railway wagons, a substantial portion of the component parts of which had been manufactured in British India. This Act was repealed by the Act No. III of 1927 and the payment of bounties consequently ceased on the 31st March 1927; the Industry is, however, protected to a certain extent by varying tariffs on different classes of imported steel.

TABLE 15.—*Exports of Pig Iron from India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
Germany	9,926	4,46,600	33,328	8,542	3,84,375	28,685
Japan	265,226	1,20,83,414	901,747	321,010	1,52,72,858	1,139,765
United Kingdom	21,140	9,51,877	71,036	8,920	4,04,166	30,162
United States of America	67,685	30,43,518	227,128	57,897	26,02,473	194,214
Other Countries	19,983	9,02,895	67,380	32,256	14,86,917	110,964
Total	**383,960**	***1,74,28,304***	***1,300,619***	**428,625**	***2,01,50,789***	***1,503,790***

Jadeite.

There was a further increase in the output of jadeite, which rose from 2,227 cwts. valued at Rs. 2,39,064 (£17,841) in 1927 to 2,845 cwts. valued at Rs. 2,85,984 (£21,342) in 1928. The output figures are liable to be incomplete, and a more correct idea of the extent of the Burmese jadeite industry is sometimes obtainable from the export figures. Exports by sea rose considerably from 1,961 cwts. valued at Rs. 3,02,440 (£22,570) in 1927-28 to 2,698 cwts. valued at Rs. 5,82,471 (£43,468) in the year 1928-29. These figures exclude exports by land across the frontier to foreign countries as the registration of the Land Frontier Trade of Burma has been discontinued.

Lead.

Although the production of lead ore at the Bawdwin mines of Burma decreased slightly from 449,817 tons in 1927 to 442,503 tons in 1928, the total amount of metal extracted increased from 65,967 tons of lead (including 503 tons of antimonial lead) valued at Rs. 2,20,27,742 (£1,643,861) to 78,384 tons of lead (including 1,241 tons of antimonial lead) valued at Rs. 2,22,05,126 (£1,657,099). The quantity of silver extracted from the Bawdwin ores also increased from 6,004,437 oz. valued at Rs. 94,67,196 (£706,507) in 1927 to 7,404,728 oz. valued at Rs. 1,19,26,055 (£890,004) in 1928. The value of lead per ton fell further from Rs. 333·9 (£24·9) in 1927 to Rs. 283·3 (£21·1) in 1928 but the value of silver rose slightly from Rs. 1-9-3 (28·24*d.*) per oz. in 1927 to Rs. 1-9-10 (28·85 *d.*) per oz. in the year under review. The ore reserves in the Bawdwin mine, as calculated at the end of June, 1928, totalled 4,092,751 tons with an average composition of 25·49 per cent. of lead, 16·0 per cent. of zinc and 21·5 oz. of silver per ton of lead. Included in this reserve are 300,000 tons of copper ore containing, approximately, 13 per cent. of lead, 8 per cent. of zinc, 7 per cent. of copper and 18 oz. of silver per ton.

Magnesite.

There was a recovery in the magnesite output from the Salem district of Madras, but the figure for 1928, 22,542 tons valued at Rs. 1,41,742 (£10,578), is still well below those for the years 1925 and 1926 which were in the neighbourhood of 30,000 tons There

TABLE 16.—*Production of Lead ore, Lead and Silver during the years 1927 and 1928.*

—	1927.					1928.				
	Quantity.	Value. (£1=Rs 13·4)				Quantity.	Value (£1=Rs. 13·4).			
	Lead ore.	Lead ore and lead.		Silver.		Lead ore	Lead ore and lead.		Silver.	
	Tons	Rs	£	Rs.	£	Tons.	Rs.	£	Rs.	£
***Burma*—**										
Northern Shan States	449,817	(a) 2,20,27,742	1,643,861	(b) 94,67,196	706,507	442,503	(c) 2,22,05,126	1,657,099	(d) 1,19,26,055	890,004
Southern Shan States	960	96,000	7,164	..	..	1,151	1,15,170	8,595	..	..
Total .	**450,777**	*2,21,23,742*	*1,651,025*	*94,67,196*	*706,507*	**443,654**	*2,23,20,296*	*1,665,694*	*1,19,26,055*	*890,004*

(*a*) Value of 65,464 tons of lead (Rs. 2,18,94,677) and 503 tons of antimonial lead (Rs. 1,33,065) extracted.

(*b*) Value of 6,004,487 oz. of silver extracted.

(*c*) Value of 77,143 tons of lead (Rs. 2,18,88,115) and 1,241 tons of antimonial lead (Rs. 3,17,011) extracted.

(*d*) Value of 7,404,728 oz. of silver extracted.

was a decrease in the output from Mysore. The total increase in output in India amounted to 4,768 tons, but it was accompanied by a decrease in value of Rs. 68,956 (£5,146).

TABLE 17.—*Quantity and value of Magnesite produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Madras—						
Salem	16,966	2,02,656	15,124	22,542	1,41,742	10,578
Mysore State . . .	2,672	26,682	1,991	1,864	18,640	1,391
Total .	**19,638**	*2,29,338*	*17,115*	**24,406**	*1,60,382*	*11,969*

Manganese.

Before the year 1926, the record production of manganese in India took place in the year 1907, when 902,291 tons were raised. In 1926, the output rose to 1,014,928 tons, valued at £2,590,357, f. o. b. Indian ports; the rise in output was, however, accompanied by a decrease in value. In 1927 the production rose to the highest yet recorded figure of 1,129,353 tons, accompanied by a rise in value to the peak figure of £2,844,237, f. o. b. Indian ports. During the year 1928, the upward tendency of manganese was not maintained, the output falling to 978,449 tons, valued at £2,321,201, f. o. b. Indian ports. In 1924, first grade ore, c. i. f. United Kingdom ports, fetched an average price of 22·9 *d.* per unit. In 1925, this price fell to 21·5*d.*, in 1926 to 18*d.* and in 1927 also to an average figure of 18 *d.* In January 1928, the unit price for best Indian and washed Georgian ore lay between 16½ *d.* and 18½ *d.* Prices remained nominally at this figure during the first half of the year, but the business done was small. During the latter half of the year it became definite that the Harriman Concession in Chiaturi in Georgia from the Soviet Government was to be terminated, and that the Soviet Government intended to work the mines themselves. Probably on this account the price of best Indian ore dropped slowly to about 16 *d.* in December. The average price for the year of first

grade ore was 17*d*. A falling price had been anticipated when it became known four or five years ago that the Harriman Group of American financiers were negotiating with the Soviet Government for the development on modern lines of the manganese ores of the Caucasus. From 1925 onwards there was, in fact, a large increase in the total output from Russia and Georgia but only to figures obtained before the War.

It might seem at first as if the termination of the Harriman interests in Russia would benefit the Indian producer. Under Soviet management, however, the cost of producing ore could be made very small. The miners are paid in paper money which costs little more than the price of printing, and the Soviet, in consequence, could afford to sell at a figure little more than that covering the carriage from the Black Sea to the consumer, *plus* a small margin of profit. A German firm has been appointed agents for the Soviet, and if their agreement be on a commission basis, it will be to their advantage to keep prices at a reasonable level. At the same time it is in their power to undersell all outsiders, and it will be to their advantage to sell as much ore as possible even perhaps at reduced rates. Their position is to some extent controlled by the fact that the manganese ore, as mined in Russia—especially that from Nikopol—requires considerable washing treatment to produce a material suitable for metallurgical uses. Cleaning plants have been erected in Russia, but the Soviet have found that from their point of view it is more economical to revert to hand-washing the ore as was done before the War. This reversion, however, will not necessarily keep down production, as the Russian export of high grade manganese ore before the War exceeded 1,000,000 tons, and there is no reason to suppose that this figure cannot again be achieved under the same methods of production. Another consolation for the Indian producer is the fact that the Russian product is small and soft and has to be mixed with a certain proportion of hard ore before it can be employed successfully.

There is little doubt that the Russians at present hold the key to the manganese situation. Unless some mutual arrangement is come to, therefore, it would be possible for them by selling at a lower price for cash to keep prices below the economic limit. Any such cartel would probably have to include producers of the lower grades of ore, as it is conceivable that the metallurgists could and might make use of a lower grade of ore if the better grades

were available only at too high a price. According to "*Die Metallbörse*" the Russian Press state that the cost of preparing first grade manganese ore for the market has increased lately by 17 per cent., owing to the lack of adequate technical supervision and of sufficient drill steel for use in breaking down the rock; the increased costs, however, appear to be spread over the washing operations as well as the actual ore-getting.

In addition to the four chief manganese-producing areas, India, Georgia (with Russia), Brazil and the Gold Coast, a further source at Postmasburg in the northern part of the Cape Province shows promise; the grade is high and the deposit extensive, the only drawback being the presence of aluminous compounds.

As the table will show, for the decrease in the output the Central Provinces are mostly responsible. All the districts of Bombay show a decrease, considerable in proportion to the output. In the case of Bihar and Orissa substantial increases in the Keonjhar State and in Singhbhum are again to be reported. The Jhabua State in Central India, which resumed production in 1924 and was making substantial progress during the last year or two, shows a drop to a little more than a third of its output in 1927. In Madras, the decrease in the case of Vizagapatam and Bellary is partially set off by an increase of some 1,600 tons from Sandur State. In the Mysore State, similarly, the decrease in the case of Chitaldrug and Tumkur is more than balanced by the increase from the Shimoga district. The four largest producing areas in India are Balaghat, Nagpur, Sandur State and Bhandara; all of them except the Sandur State showed a substantial decline in production.

The exports of manganese ore in 1927 showed an increase of 230,000 tons, which was less than 20,000 tons short of the highest export recorded, namely, 862,777 tons in 1922. There was a decrease of exports in 1928, amounting to some 9,677 tons. The proportional fall in the case of exports was, therefore, much less than that in the case of output.

There is a steady consumption of manganese at the works of the three principal Indian iron and steel companies, not only for use in the steel furnaces of the Tata Iron and Steel Co., and for the manufacture of ferro-manganese, but also for addition to the blast furnace charge in the manufacture of pig iron. The consumption of manganese ore by the Indian iron and steel industry in the year under review amounted to 69,872 tons, against 39,065 tons in 1927.

TABLE 18.—*Quantity and value of Manganese ore produced in India during the years 1927 and 1928.*

—	1927.		1928.	
	Quantity.	Value, f.o.b. at Indian ports.	Quantity.	Value, f.o.b. at Indian ports.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Gangpur State	7,960	20,928	6,379	16,134
Keonjhar State	51,115	103,721	72,411	140,59[illegible]
Singhbhum	9,970	26,213	23,199	58,674
Bombay—				
Chhota Udaipur	11,729	30,398	7,267	18,12[illegible]
Belgaum	4,515	11,871	1,603	4,054
North Kanara	4,005	10,530	3,601	9,107
Panch Mahals	78,802	207,184	63,040	159,439
Central India—				
Jhabua State	10,510	22,728	3,835	7,926
Central Provinces—				
Balaghat	313,556	871,424	248,497	663,694
Bhandara	130,211	361,878	89,059	237,862
Chhindwara	47,264	131,355	37,069	99,005
Jubbulpore	181	503	..	..
Nagpur	252,637	702,120	216,509	578,259
Madras—				
Bellary	6,004	9,782	5,257	8,236
Sandur State	138,196	225,144	139,801	219,021
Vizagapatam	31,992	56,386	29,094	49,217
Mysore State—				
Chitaldrug	4,021	6,819	1,907	3,107
Shimoga	23,658	40,120	27,994	45,607
Tumkur	3,027	5,133	1,927	3,139
Total	**1,129,353**	*2,844,237*	**978,449**	*2,321,201*

Table 20 shows the distribution of manganese ore exported from British Indian ports (excluding the Portuguese port of Mormugao) during 1927 and 1928, from which it will be seen that the United Kingdom has again lost her position as chief importer of Indian manganese ore, and in 1928 ranked after France and Belgium. France increased her imports by over 44,000 tons. Belgium increased hers by over 9,000 tons, while the decrease in the

United Kingdom amounted to over 52,000 tons. Germany who doubled her imports in 1927 showed again a substantial increase of over 8,000 tons in 1928. The Netherlands again showed a decrease, this time amounting to 5,000 tons. Italy, which had dropped behind in 1927, recovered her position in 1928. Japan, which took no less than 15,500 tons from India in 1927, has ceased importing. The supply to the United States dropped from 97,500 to 76,000 tons. Other countries increased their takings by over 4,900 tons.

TABLE 19.—*Exports of Manganese ore during 1927 and 1928, according to Ports of Shipment.*

Port.	1927.	1928.
	Tons.	Tons.
Bombay	249,360	270,961
Calcutta	418,173	378,604
Madras	13,910	9,002
Mormugao (Portuguese India)	162,378	175,577
Total	**843,821**	**834,144**

TABLE 20.—*Exports of Manganese ore from British Indian Ports during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
United Kingdom	211,401	55,70,789	415,730	159,227	44,77,671	334,154
Germany	12 805	2,99,967	22,386	20,945	5,49,002	40,970
Netherlands	12,500	3,52,000	26,269	7,501	2,45,525	18,323
Belgium	174,485	50,33,543	375,637	183,897	51,61,358	385,176
France	151,100	42,26,544	315,414	195,576	57,34,567	427,953
Italy	5,150	1,85,250	13,825	9,475	3,17,387	23,68[illegible]
Japan	15,502	3,44,481	25,708	..	..	..
United States of America	97,500	27,22,502	203,171	76,000	22,44,750	167,519
Other Countries	1,000	34,250	2,556	5,946	2,24,093	16,790
Total	681,443	*1,87,69,326*	*1,400,696*	658,567	*1,89,55,253*	*1,414,571*

Mica.

There was a further increase in the declared production of mica from 24,614 cwts. valued at Rs. 24,52,055 (£182,989) in 1927 to 45,112 cwts. valued at Rs. 24,10.499 (£179,887) in 1928. As has

been frequently pointed out, the output figures are incomplete, and a more accurate idea of the size of the industry is to be obtained from the export figures. It will be seen from Table 22 that in the year 1928 the quantity exported was more than double the reported production. In both the years 1926 and 1927 also the export figure was approximately double the reported production figure. The United States of America and the United Kingdom, which are the principal importers of Indian mica, absorbed 23·7 per cent. and 49·4 per cent., respectively, of the total quantity exported during 1927 and 25·1 per cent. and 44·6 per cent., respectively, during 1928. Germany took 14·2 per cent. and 16·0 per cent., respectively, of the total quantities exported during the years 1927 and 1928. The average value of the exported mica fell considerably from Rs. 119·5 (£8·9) per cwt. in 1927 to Rs. 98·0 (£7·3) per cwt. in 1928.

The difference between exports and production is generally attributed to theft from the mines. If this be the only explanation we must assume that during the past three years there has been as much mica stolen as won by honest means. Early in 1928 a bill was introduced into the Legislative Council of Bihar and Orissa, the purpose of which was an attempt to reduce the losses on this account by licensing miners and dealers; the bill was, however, rejected.[1]

TABLE 21.—*Quantity and value of Mica produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
Bihar and Orissa—						
Gaya	1,513	1,08,926	8,129	2,452	1,00,704	7,515
Hazaribagh	29,419	16,07,216	119,942	32,419	17,61,507	131,456
Monghyr	615	28,063	2,094	267	14,084	1,051
Sambalpur	17	418	31	5	131	10
Gwalior	240	7,431	555	140	6,877	513
Madras—						
Nellore	9,265	5,93,374	44,281	8,838	4,77,328	35,621
Nilgiris	281	39,612	2,956	109	10,068	751
Rajputana—						
Ajmer-Merwara	971	49,752	3,713	539	29,733	2,219
Jaipur	4	400	30	..	..	..
Shahpura	289	16,863	1,258	343	10,067	751
TOTAL	42,614	*24,52,055*	*182,989*	45,112	*24,10,499*	*179,887*

[1] A similar bill is, however, being brought up in the Council this year (1929).

TABLE 22.—*Quantity and value of Mica exported from India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4)		Quantity.	Value (£1 = Rs. 13·4).	
	Cwts.	Rs.	£	Cwts	Rs.	£
To—						
United Kingdom	38,298	43,00,239	320,913	42,556	45,91,826	342,674
Germany	11,014	8,69,478	64,887	15,286	11,11,349	82,936
France	3,876	3,71,246	27,705	3,983	4,29,509	32,053
United States of America	18,410	30,73,548	229,369	23,968	22,39,370	167,117
Other Countries	5,890	6,49,461	48,467	9,686	9,82,892	73,350
TOTAL	77,488	*92,63,972*	*691,341*	95,479	*93,54,946*	698,130

Monazite.

The monazite industry of Travancore, which was almost dead in the year 1925, when the reported production was 1 cwt. only, showed signs of revival in 1926, the output amounting to 64·2 tons valued at £947. The production rose to 280 tons valued at £3,810 in 1927 but fell again to 103·4 tons valued at £1,242 in 1928. The decline of the industry is of course due to the supplanting of incandescent mantles for gas lighting by electricity. It is hoped that ilmenite, collected with the monazite and hitherto regarded as a by-product, may be the means of reviving the industry; titania forms a valuable white paint superior to white lead in being non-poisonous and in possessing twice the covering power.

Nickel.

As a by-product in the smelting operations of the Burma Corporation, Limited, at Namtu, in the Northern Shan States, there is now a regular production of nickel speiss, which in 1927 amounted to 1,032 tons valued at Rs. 1,76,554 (£13,176) containing 24·64 per cent. of nickel, 15·92 per cent. of copper and also 33·58 oz. of silver to the ton. The production in 1928 rose to 2,933 tons averaging 24·8 per cent. of nickel, 15·2 per cent. of copper and also containing 32·2 oz. of silver to the ton. The value of the production in

1928 is estimated at Rs. 5,34,961 (£39,922). This speiss is shipped to Hamburg for further treatment. It contains from 3 to 4 per cent. of cobalt.

Petroleum.

The world's production of petroleum in 1926 amounted to a little over 151½ million metric tons, of which India contributed 0·79 per cent. In 1927, this figure jumped to some 171 million metric tons, of which the Indian proportion, on a practically stationary production, fell to 0·72 per cent. In 1928 there was another substantial rise in the world's production which reached the record figure of over 180 million metric tons. For this rise Venezuela was mostly responsible, but Russia, Persia, Roumania, Columbia, the Dutch East Indies, Peru, the Argentine, India, Trinidad and smaller producers all contributed to the increase. There was a decline in the case of the United States and Mexico. The former of these two countries has now adopted a conservative policy, and this is likely to have a restraining effect upon the world's production figure in the early future. Nevertheless the United States contributed over 67 per cent. of the world's supply in 1928, mostly from the mid-continent and Californian fields. Of the total world's production in 1928, India contributed 0·685 per cent.; she is still 11th on the list of petroleum-producing countries, but is being challenged by Trinidad who was 12th on the list in the year under review.

Although petroleum statistics prove that it is becoming more and more difficult to maintain the output of India (including Burma) at the high levels it reached in 1919 and 1921. when peak productions of well over 305½ million gallons were reached, the production during 1928 reached the figure of 305,943,711 gallons, which is the highest ever recorded. In spite of the fact that there was an increase in output not far short of 25 million gallons, there was a decrease in the value of the product amounting to Rs. 14,37,289 (£107,261). The refinery through-put was not increased, the excess of production over what was needed having been used to restore depleted stocks of crude oil. The increase in output, notable as it is, can only be regarded as an arrest in the decline which has set in and which, with possible interruptions, is likely to continue slowly and steadily during the present generation, unless a new field of importance is discovered. The chances of the latter recede year after year as exhaustive geological research continues to prove fruitless. A con-

servative policy rather than one of intensive development is indicated especially in view of the national importance of this mineral asset.

The Yenangyaung field of Upper Burma, the most highly developed field in the Indian Empire, again shows a decline in output. In 1924, it succeeded in showing an increase of nearly 6½ million gallons but this temporary arrest in the decline was more than neutralised by a drop in 1925 of over 21½ million gallons. In 1926, the drop amounted to 14¼ million gallons, in 1927 to 8⅔ million gallons and in 1928 to 1⅓ million gallons. It is interesting to note that the production in Yenangyaung still includes oil derived from the old Burmese hand-dug wells.

In the Yenangyaung field it is now seldom that a new well strikes a yield of over 50 barrels per initial 24 hours, nearly all the exceptions occurring in the Kodaung tract. The higher production from the Burmah Oil Company's wells in Kodaung is due in part to the geological position of the block and to the relatively youthful stage of its producing life, but in the main to the proper scientific system of development it has been possible to adopt there, as compared with the intensive competitive drilling in the reserved areas, where practically every well interferes with the production of its neighbours. The number of producing wells in the Yenangyaung field in 1928 amounted to nearly 2,450, including about 150 hand-dug wells. More than a quarter of these wells were making water at the average rate of over 1,260 gallons per day, against an average daily yield of oil amounting to some 2,030 gallons. The utilization of the shallow oil sands of these fields, which were shut off during the competitive rush for the richer deep sands, continues. Many remunerative wells are now being worked from two shallow zones, one at about 350 feet and the other at about 650 feet; the production from the shallow wells during 1927 amounted, in fact, to nearly 14 per cent. of the total production from the field. Intensive drilling of shallow wells continues, but, in spite of the fact that the fall in the yield of these wells is unexpectedly gradual, the effect in delaying the decline of the field may be looked upon as but temporary. The average daily yield of the shallow wells varies from 1½ to 2 barrels each. The electrification of the field, which reached its limit of practicability in 1924, has added and is adding an appreciable contribution to the production figure, owing to the saving of a considerable quantity of crude oil formerly used as fuel beneath rig-boilers,

The relative merits of repressuring and suction are now exercising the minds of operators in Yenangyaung. It seems probable that both processes, employed at the proper time, will be found useful in increasing the yield from the various sands to which they are applied. To make full use of gas pressure in the oil sands, it would appear advantageous to use the repressuring process as long as possible and to postpone the use of vacuum. The adverse effects of vacuum are not only the removal of the driving force in the form of gas, but an abstraction of the lighter components of the crude oil causing earlier paraffination of the sands. On the other hand, it is difficult to decide to what extent the results of repressuring are an actual increase in the total crude oil extracted from the sand, or merely accelerated production.

Of the several companies operating in this small field, the Burmah Oil Company produce about four-fifths of the total output. Of the undrilled portions of the Yenangyaung field, the northern areas are showing more promise than the southern. A test well put down in block 2S is now the deepest well in Burma, having reached a depth of 5,267 feet. Oil and gas sands are reported to have been struck below 5,000 feet, but trouble with the well has so far prevented any estimation of the yield. The results of the test of these reported oil sands will be awaited with considerable interest, since the proving of rich oil sands at that depth would appreciably increase the prospects of the whole Yenangyaung field. At the moment, however, undue optimism is unwarranted. There is now good reason to believe that, as the depth increases, the crest of the Yenangyaung anticline recedes more and more to the east; this means that the producing limits of oil pools will be found further and further eastwards as greater depths are attained. Deep test wells are being put down to prove this. On the eastern flank of the anticline, an advance of "edge" water has shown itself up one of the oil sands. During the year there were 11 outbreaks of fire; from one of these the damage was *nil*, and from the rest no serious loss or damage of life or property resulted. Out of 125 accidents reported during 1928, only 5 were fatal. The price of hand-dug oil at the river bank during the year in question averaged about Rs. 12-11-0 during the first half of the year, and Rs. 11-12-0 during the second half.

The place of Yenangyaung is being steadily taken by the Singu field which, in a few years, will undoubtedly usurp the premier

position so far held by the older field. Singu, the greater part of which is in the hands of the Burmah Oil Company, is used to make good the deficiencies of Yenangyaung in order to maintain supplies to the refinery. Owing to a more intensive drilling in Singu by the above company, the output in 1928 exceeded the output of 1927 by over 15¼ million gallons. Many wells are producing from the second or 3,000-foot sand; the margin of the latter has been found to be inside that of the shallower sand in the southern end of the field, but outside it, in the northern end. With regard to the electrification of the field, the transmission line from Yenangyaung was completed in 1927, and a number of wells are now being pumped and drilled by electric power. Lighting has also been provided at the northern end of the field and power to the machine shops.

Drilling was first started on the Yenangyat field in 1891 by the Burmah Oil Co. The expansion was slow up to 1894, but rose rapidly to a yield of over 6 million gallons in 1898, and in 1903 the highest quantity recorded from this field was produced, namely, 22,665,518 gallons. Subsequent to that year, a decline set in, gradual at first, but severe after 1906. Between 1909 and 1918, production averaged a little over 5 million gallons. From 1918 onwards the decline was gradual but persistent until 1925 when it had sunk to a little more than 1½ million gallons. Since 1925, there has been a gradual recovery. In 1927, the output was 1,844,946 gallons. In 1928, the yield rose to 3,072,222 gallons, a stride due to increased drilling on the part of the Burmah Oil Company and also to expansion by the Indo-Burma Petroleum Company in the Lanywa area in the south. A scheme, by which the sandbank stretching southwards from the wells of Lanywa into the river Irrawaddy is to be protected by a rivetted embankment, is being carried out, and has enabled a number of wells to be drilled by the Indo-Burma Petroleum Company on the sandbank. Strictly speaking, the area belongs tectonically to the Singu dome area, but for convenience of administration it is regarded officially as part of the Yenangyat field. The sandbank which stretches from Lanywa to Sitpin is a more or less permanent feature, dry during the winter but covered by the floods of the rainy season. As remarked before, the striking of remunerative supplies of oil at Lanywa makes it almost certain that the river Irrawaddy covers oil deposits of commercial size. The question of reaching the

sub-fluviatile deposit, by means of a tunnel beneath the river large enough to accommodate drilling derricks, is now under consideration.

Of the other Burma fields, Minbu again showed an increase amounting to over 900,000 gallons. Owing to the rate war, the deep tests in this field were for the most part shut down during the year. Some 220 wells were producing. The heavy oil from Minbu is less profitable to refine than that produced from other fields. There was a noticeable improvement in the case of the Upper Chindwin, which showed an increase amounting to over 480,000 gallons. The Thayetmyo field, which had shown a slight recovery in 1927, declined again to the extent of over 272,000 gallons. Tests are being carried out at Minhla. The outputs from Kyaukpyu and Akyab remained at their usual low level.

In Assam, the Digboi field shewed a marked increase amounting to over 6 million gallons. Owing to the rate war the Company derived no profit from this increased output and were, in fact, faced with a loss of over £222,500, making a total loss to be carried forward of nearly £402,000. The extensions to the refinery were practically completed during the year under review and are now available to deal with the increased production for which the company have planned. Geological investigations by the Assam Oil Company's staff have aroused expectations of successful extension of the Digboi field. Prospecting operations at Dhekiajuli, Dilli and Burragolai have been disappointing; oil was obtained in the Burragolai well, but the quantity was insufficient to be of commercial value. The output from Badarpur was increased by nearly 820,000 gallons as a result of the rate war. Fifty-seven wells have been drilled on this field with disappointing results. Drilling difficulties are unusually great, the decrease in yield from the wells is unusually rapid, and the deeper tests—over 3,000 feet - which at first aroused hopes, have shown the same rapid decline in yield as the shallow sands. The small production from the Masimpur area increased by about 300 gallons; the same water trouble was experienced in the 4 wells drilled. The Patharia area is being tested by a second well.

In the Punjab, the output from the Khaur field shewed another increase, this time amounting to nearly 1,600,000 gallons. The bulk of this oil was obtained from the 3,100-foot and 3,300-foot sands. Towards the latter part of the year deeper sands were proved at 3,600

and 3,800 feet, and these—especially the latter—were found to be satisfactory producers.

There was a marked increase in the imports of kerosene, the countries responsible for this increase being Persia chiefly, and, to a lesser extent, Russia, Georgia, Borneo, Sumatra and other countries. Imports from the United States of America fell from over 60¼ million gallons to not quite 17 million gallons. There was also a decrease amounting to nearly 5¼ million gallons from the Straits Settlements.

The quantity of fuel oil imported into India during 1928 was, as Table 25 will shew, nearly 633,000 gallons more than that received during the previous year. The total imports for the year under review being a little under 101 million gallons. Some four-fifths of the supply was derived from Persia and the greater part of the rest from Borneo.

The export of paraffin wax again increased to the extent of nearly 2,000 tons more than it was during the previous year (see Table 26).

TABLE 23.—*Quantity and value of Petroleum produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Gals.	Rs.	£	Gals.	Rs.	£
Assam—						
Badarpur . .	1,912,593	4,98,937	37,234	2,730,576	7,12,324	53,159
Digboi . .	22,604,187	38,59,866	288,050	28,745,932	49,08,624	366,315
Masimpur . .	25,485	6,648	496	25,780	6,725	501
Burma—						
Akyab . .	5,627	1,948	145	5,260	2,428	181
Kyaukpyu . .	15,452	15,687	1,171	15,227	14,325	1,069
Minbu .	5,199,950	11,10,406	82,866	6,101,822	11,44,091	85,380
Singu . .	98,691,487	2,09,71,930	1,565,069	113,986,736	2,13,72,513	1,594,964
Thayetmyo . .	999,500	2,12,394	15,850	727,322	1,37,623	10,270
Upper Chhindwin .	1,825,120	1,36,884	10,215	2,308,880	1,73,166	12,923
Yenangyat . .	1,844,946	3,84,359	28,685	3,072,222	5,76,041	42,988
Yenangyaung .	137,322,012	2,93,81,716	2,192,665	135,969,794	2,56,98,986	1,917,835
Punjab—						
Attock.	10,667,600	26,66,900	199,022	12,254,160	30,63,540	228,622
TOTAL .	281,113,909	*5,92,47,675*	*4,421,468*	305,943,711	*5,78,10,386*	*4,314,207*

TABLE 24.—*Imports of Kerosene Oil into India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Gals.	Rs.	£	Gals.	Rs.	£
From—						
Russia	2,329,308	13,10,236	97,778	14,169,538	79,20,135	591,055
Georgia	10,248,988	59,88,067	446,871	20,515,333	99,73,065	744,259
Persia	2,287,404	9,79,734	73,114	33,530,023	1,68,33,736	1,256,249
Straits Settlements (including Labuan)	5,294,469	23,05,617	172,061	73,730	43,536	3,249
Sumatra	13,000	13,338	995	2,074,130	11,87,178	88,595
Borneo	7,734,388	40,11,512	299,367	15,152,333	78,55,377	586,222
United States of America.	60,250,875	4,04,81,594	3,021,015	16,954,999	1,15,59,044	862,615
Other Countries	195	198	15	1,969,880	5,96,200	44,493
TOTAL	88,158,627	*5,50,90,296*	*4,111,216*	104,439,966	*5,59,68,271*	*4,176,737*

TABLE 25.—*Imports of Fuel Oils into India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4)		Quantity.	Value (£1 = Rs. 13·4)	
	Gals.	Rs.	£	Gals.	Rs.	£
From—						
Persia	77,872,989	1,58,09,773	1,179,834	81,826,295	1,50,70,870	1,124,602
Straits Settlements (including Labuan)	3,615,530	11,09,000	82,761	4,713,687	16,85,345	125,772
Borneo	16,316,240	45,71,636	341,167	14,140,215	35,28,120	263,292
Other Countries	2,480,777	6,85,771	51,177	238,260	81,052	6,049
TOTAL	100,285,536	*2,21,76,180*	*1,654,939*	100,918,457	*2,03,65,387*	*1,519,805*

TABLE 26.—*Exports of Paraffin Wax from India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4)	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
United Kingdom	14,398	67,48,807	503,642	11,511	53,22,111	397,172
Germany	2,909	13,33,292	99,499	3,227	15,03,519	112,203
Netherlands	3,537	16,11,254	120,243	5,492	25,07,960	187,161
Belgium	5,783	26,76,485	199,738	5,717	25,47,836	190,137
China	2,897	13,91,856	103,870	4,734	22,03,066	164,408
Union of South Africa.	2,340	10,79,881	80,588	2,179	10,05,830	75,062
Portuguese East Africa.	4,568	26,98,359	201,370	2,780	16,93,133	126,353
United States of America.	2,380	10,83,850	80,884	4,065	18,49,575	138,028
Australia	867	3,94,628	29,450	914	4,16,778	31,103
New Zealand	464	2,11,574	15,789	351	1,59,705	11,918
Other Countries	7,557	34,50,718	257,516	8,697	39,67,581	296,088
TOTAL	47,700	*2,26,80,704*	*1,692,569*	49,676	*2,31,77,094*	*1,729,633*

Ruby, Sapphire and Spinel.

A severe decline in the output from the Mogok ruby mines of Upper Burma in 1924, followed in 1925 by a marked drop in value, bore witness to a serious decline in the industry. The Burma Ruby Mines, Ltd., ultimately decided to go into liquidation, and the mines were offered for sale in September 1926. The skeleton organisation left in charge of the mines, however, made good use of its opportunities with the result that the value of the output in 1926 exceeded that of the previous year by over a lakh of rupees. This encouraging result was effected by a rigorous economy and an extension of a system of co-operation with local miners, and was assisted by some good finds of sapphires in the Kyaungdwin mine—the only one still worked by European methods.

During 1927, however, production fell in value by over 1¾ lakhs of rupees, due mainly to a decrease in the value of the sapphires and spinels produced, there having been a slight increase in the value of the rubies. During 1928, there was another very large decline in value, amounting to over a lakh of rupees, due to a severe drop in the value of the sapphires produced; as before, there was a slight increase in the value of the rubies.

The production of "corundum with sapphire patches" in Kashmir during 1928 amounted to 1 cwt. only. The production in 1927 amounted to 11 cwts. and in 1926 to 1·6 cwts. The value in each case was not stated.

TABLE 27.—*Quantity and value of Ruby, Sapphire and Spinel produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Carats.	Rs.	£	Carats.	Rs.	£
Burma	(a)	1,18,000 (Rubies).	8,806	32,010 (Rubies).	1,22,181	9,118
	(a)	1,61,500 (Sapphires).	12,052	4,500 (Sapphires).	54,853	4,093
	(a)	334 (Spinels).	25	3,870 (Spinels).	478	36
TOTAL .	(a)	*2,79,834*	*20,883*	40,380	*1,77,512*	*13,247*

(a) Quantity not reported.

Salt.

There was an appreciable decrease in the total output of salt amounting to 96,596 tons, the two chief contributors to the decline being Madras and Northern India. Aden shewed an increase of 41,014 tons and Bombay and Sind an increase of 27,880 tons. There was a small increase from Burma.

TABLE 28.—*Quantity and value of Salt produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1=Rs. 13·4).		Quantity.	Value (£1=Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Aden	181,757	8,74,489	65,260	222,771	18,66,844	139,317
Bombay and Sind	432,993	23,12,426	172,569	460,873	25,82,690	192,738
Burma	19,913	5,52,196	41,209	21,322	5,17,226	38,599
Gwalior (a)	435	23,362	1,743	60	3,107	232
Kashmir	1	56	4	2	58	4
Madras	543,081	47,63,741	355,503	448,538	26,36,046	196,720
Northern India	433,765	28,53,885	212,977	361,783	23,89,079	178,289
TOTAL	1,611,945	*1,13,80,155*	*849,265*	1,515,349	*99,95,050*	*745,899*

(a) Figures relate to official years 1927-28 and 1928-29.

TABLE 29.—*Quantity and value of Rock-salt produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1=Rs. 13·4).		Quantity.	Value (£1=Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Salt Range	145,750	8,45,720	63,113	131,730	7,83,794	58,492
Kohat	21,161	68,225	5,092	19,812	63,276	4,722
Mandi	3,837	92,112	6,874	3,811	91,494	6,828
Total	**170,748**	*10,06,057*	*75,079*	**155,353**	*9,38,564*	*70,042*

TABLE 30.—*Imports of Salt into India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
From—						
United Kingdom	83,523	27,56,487	205,708	76,238	22,44,002	167,463
Germany	55,027	16,73,437	124,883	62,619	17,08,170	127,476
Spain	89,328	25,63,902	191,336	67,979	17,25,810	128,792
Aden and Dependencies	182,696	54,40,838	406,033	201,167	49,04,564	366,012
Egypt	148,873	42,43,591	316,686	112,718	27,32,158	203,892
Italian East Africa	63,062	17,36,872	129,617	55,505	13,04,626	97,360
Other countries	15,185	4,38,786	32,745	38,196	8,17,298	60,992
Total	**637,694**	*1,88,53,913*	*1,407,008*	**614,417**	*1,54,36,628*	*1,151,987*

Saltpetre.

Although statistics of production of saltpetre in India are no longer available, the export figures may be accepted as a fairly reliable index to the general state of the industry. Excepting a few hundreds of tons required for internal consumption as fertilizer, most of the output is exported to foreign countries. The quantity exported in 1928 amounted to 89,570 cwts. valued at Rs. 10,00,034 (£74,629) against 123,018 cwts. valued at Rs. 15,22,666 (£113,632) in 1927.

A certain amount of nitrate of potash is used for agricultural purposes on the tea gardens of India. During the war when it was impossible to obtain supplies of imported potash the amount of locally produced nitrate utilized in this way reached an appreciable figure. The practice continued and the quantities estimated to have been absorbed for fertilising purposes on tea gardens in 1923, 1924, 1925, 1926, and 1927 were 1,000, 1,100, 800, 700 and 500 tons respectively. In 1928 this figure is estimated to have been 250 tons only. The gradual decrease since the year 1925 is due to the fact that it is found cheaper to employ a mixture of imported sulphate of ammonia and muriate of potash.[1]

[1] From information kindly supplied by Messrs. Shaw, Wallace & Co.

TABLE 31.—*Distribution of Saltpetre exported from India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
To—						
United Kingdom . .	13,320	1,54,074	11,498	16,224	1,95,348	14,578
Ceylon	86,410	9,42,667	70,348	62,630	6,04,892	45,141
Straits Settlements (including Labuan).	3,856	57,548	4,295	2,868	44,427	3,316
Hongkong. . . .	2,050	92,300	6,888	..	..	..
Mauritius and Dependencies	13,870	2,12,907	15,889	6,084	1,14,680	8,558
Other countries . .	3,512	63,170	4,714	1,764	40,687	3,036
Total .	123,018	*15,22,666*	*113,632*	89,570	*10,00,034*	*74,629*

Silver.

There was again a notable increase in the production of silver from the Bawdwin mines of Upper Burma, amounting to 1,400,291 oz. The output of silver obtained as a by-product from the Kolar gold mines of Mysore increased to the extent of 862 oz.

TABLE 32.—*Quantity and value of Silver produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	oz.	Rs.	£	oz.	Rs.	£
Burma—						
Northern Shan States .	6,004,437	94,67,196	706,507	7,404,728	1,19,26,055	890,004
Madras—						
Anantapur . . .	149	125	9	..	..	..
Mysore—						
Kolar . . .	20,220	31,220	2,330	21,082	32,916	2,456
Total .	6,024,806	*94,98,541*	*708,846*	7,425,810	*1,19,58,971*	*892,460*

Tin.

A considerable decrease in the production of tin ore in Burma has to be reported for the year under review, during which the output amounted to 2,780 tons, valued at Rs. 45,41,201 (£338,895), against 3,495 tons valued at Rs. 66,17,773 (£493,864) in the preceding year. This decrease of 715 tons is somewhat fictitious, as the figures for 1928 do not include 218 tons of low grade complex wolfram-scheelite-cassiterite ore recovered from the mine dumps of Mawchi in the Southern Shan States, and purchased from tributors for £4,018. No milling operations were performed, and the percentage composition of the mixed ore is, therefore not precisely known. The figure for 1927 included 836 tons from Mawchi, calculated to be the proportion of tin ore in 1,466 tons of concentrates derived from 27,266 tons of mixed wolfram-scheelite-cassiterite ore; these concentrates were assumed to contain 43 per cent. of wolfram and 57 per cent. of cassiterite. There is no reported output of block tin.

Imports of unwrought tin decreased from 60,529 cwts. valued at Rs. 1,16,72,352 (£871,071) in 1927 to 56,316 cwts., valued at Rs. 92,22,619 (£688,255) in 1928; over 96 per cent. of these imports came from the Straits Settlements. Wrought tin, to the extent of 197 cwts. valued at Rs. 39,697 (£2,962), was also imported into India during the year under review.

TABLE 33.—*Quantity and value of Tin ore produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Burma—						
Amherst . . .	..	..	..	9	10,917	815
Mergui . . .	1,163	26,04,760	194,385	1,052	19,05,857	142,228
Southern Shan States .	836	(*a*) 15,82,548	118,101	..	..	..
Tavoy . . .	1,489	24,15,465	180,259	1,712	26,15,122	195,158
Thaton . . .	7	15,000	1,119	7	9,305	694
Total .	**3,495**	***66,17,773***	***493,864***	**2,780**	***45,41,201***	***338,895***

(*a*) Estimated.

TABLE 34.—*Imports of unwrought Tin (blocks, ingots, bars and slabs) into India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
From—						
United Kingdom . .	871	1,79,418	13,389	1,231	2,03,419	15,180
Straits Settlements (including Labuan).	59,234	1,14,15,558	851,907	54,205	88,85,003	663,060
Other countries . .	424	77,376	5,775	880	1,34,197	10,015
Total .	**60,529**	*1,16,72,352*	*871,071*	**56,316**	*92,22,619*	*688,255*

Tungsten.

The reported output of wolfram again decreased from 1,160 tons in 1927 to 622 tons in 1928, but a little over 218 tons of low grade complex wolfram-scheelite-cassiterite ore, recovered from the mine dumps of Mawchi in the Southern Shan States of Burma and purchased from tributors for £4,018, have been omitted from the figure for 1928, since no milling operations were undertaken and the percentage composition of the mixed ore is not precisely known. The figure for 1927 includes 630 tons from Mawchi, calculated to be the proportion of wolfram in 1,466 tons of concentrates (assumed to contain 43 per cent. of wolfram and 57 per cent. of cassiterite) derived from the milling of 27,266 tons of mixed wolfram-scheelite-cassiterite ore.

Tavoy recovered from 522 tons in 1927 to 593 tons in 1928, but is still well below the figure for 1926, 742 tons.

TABLE 35.—*Quantity and value of Tungsten ore produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Burma—						
Mergui	8	4,070	304	29	11,697	873
Southern Shan States .	630	(a) 3,09,330	23,084	..	..	..
Tavoy	522	2,56,603	19,149	593	2,87,852	21,481
Total .	1,160	*5,70,003*	*42,537*	622	*2,99,549*	*22,354*

(a) Estimated.

Zinc.

The production of zinc concentrates by the Burma Corporation, Limited, in the Northern Shan States, rose from 58,286 tons valued at Rs. 73,19,468 (£546,229) in 1927 to 64,122 tons valued at Rs. 74,96,118 (£559,412) in 1928. The exports during the year under review amounted to 76,031 tons valued at Rs. 74,10,889 (£553,051) against 67,135 tons valued at Rs. 70,06,018 (£522,737) in the preceding year.

Zircon.

The output of zircon, a mineral obtained as a concurrent product in the collection of ilmenite and monazite in Travancore State, decreased from 1,465 tons valued at £8,129 in 1927 to 855·2 tons valued at £4,267 in 1928, in spite of a conspicuous increase in the production of ilmenite.

III—MINERALS OF GROUP II.

Alum.

The output of alum in the Mianwali district, Punjab, amounted to only 478 cwts. valued at Rs. 5,525 (£412) in 1928 against 1,419 cwts. valued at Rs. 23,160 (£1,728) in 1927.

Amber.

The production of amber in the Myitkyina district, Burma, decreased from 70·6 cwts. valued at Rs. 27,180 (£2,028) in 1927 to 29·5 cwts. valued at Rs. 12,020 (£897) in 1928.

Apatite.

The production of apatite in the Singhbhum district, Bihar and Orissa, rose from 603 tons valued at Rs. 10,045 (£750) in 1927 to 805 tons valued at Rs. 14,490 (£1,081) in 1928.

Asbestos.

There was an increase in the total production of asbestos which amounted to 156·5 tons valued at Rs. 21,735 (£1,622) in 1928 against 67·7 tons valued at Rs. 13,554 (£1,011) in 1927. 148 tons were produced in the Seraikela State of Bihar and Orissa, and 8·5 tons in the Cuddapah district, Madras.

Barytes.

Of the total production of 3,096 tons of barytes valued at Rs. 19,610 (£1,463), 620 tons were produced in the Kurnool district, Madras, and 2,476 tons in the Alwar State, Rajputana. The production in 1927 amounted to 1,719 tons valued at Rs. 9,890 (£738).

Bauxite.

There was a large increase in the total production of bauxite, which rose from 4,310 tons valued at Rs. 28,240 (£2,107) in 1927 to 14,667 tons valued at Rs. 94,253 (£7,034) in 1928. 11,167 tons were produced in the Kaira district of Bombay and 3,500 tons in the Jubbulpore district of the Central Provinces. It is gratifying to find India increasing her output to such a substantial extent. British Guiana is now the largest producer in the British Empire but is far below France.

Bismuth.

The production of native bismuth rose from 48 lbs. valued at Rs. 128 (£10) in 1927, to 82 lbs. valued at Rs. 267 (£20) in 1928.

Borax.

Borax is produced from the Puga Valley in the Ladakh tahsil of Kashmir State. The production amounted to 15 cwts. valued at Rs. 22 (£1·6) in 1928 against 3·6 cwts. valued at Rs. 20 (£1·5) in the previous year.

Building materials and road-metal.

The total estimated value of building materials and road-metal produced in the year under consideration was Rs. 1,48,86,160 (£1,110,907). Certain returns supplied in cubic feet have been converted into tons on the basis of certain assumed relations between volume and weight. The total production of 3,181,867 tons of limestone and *kunkar* includes the production of 17,990 tons of dolomite produced in the Gangpur State, Bihar and Orissa, mainly for use as flux in the iron and steel industry, and 85 tons in the Jaisalmer State, Rajputana, used for building purposes (see Table 36). This decreased production, of dolomite in Gangpur compared with 1927 (59,679 tons) is due to the progressive replacement by limestone as a flux in the iron and steel industry.

TABLE 36.—*Production of Building Materials*

	Granite and Gneiss.		Laterite.		Lime.		Limestone and Kankar	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.
Assam	26,145	47,397	22,173	33,005	..	..	66,700	1,05,311
Bengal	94,629	70,533	..	..	..	..	..	..
Bihar and Orissa . .	283,181	3,89,165	3,184	776	..	..	(a) 805,865	17,12,623
Bombay	..	..	2,520	5,265	..	..	..	..
Burma	637,990	18,08,440	282,190	4,98,866	..	..	215,753	3,63,604
Central India . .	..	..	..	..	17,381	1,79,208	113,705	72,749
Central Provinces . .	90	470	681	596	..	..	673,627	9,06,737
Gwalior	..	..	..	..	..	..	..	..
Kashmir	..	..	..	..	132	4,450	..	..
Madras	12,323	7,597	87,585	81,715	..	..	16,180	15,436
Mysore	..	..	1,593	2,684	7,675	1,81,942	3,228	4,098
N.-W. F. Province . .	..	..	..	..	..	..	11,037	8,112
Punjab	..	..	..	..	..	..	494,102	7,49,800
Rajputana	..	..	..	..	..	..	(b) 200,946	3,25,960
United Provinces . .	..	..	..	..	..	..	(c) 580,724	7,16,798
Total .	**1,054,358**	***23,23,602***	**399,926**	***6,22,907***	**25,188**	***3,65,600***	**3,181,867**	***49,81,228***

(a) Includes 17, 990 tons of dolomite.
(b) Includes 85 tons of dolomite.
(c) Includes 564,384 tons of *kankar* used for metalling roads.

and Road-metal in India during 1928.

Marble		Sandstone.		Slate.		Trap.		Miscellaneous.		Total value (£1 = Rs. 13·4)	
Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Rs.	£
..	..	6,168	14,559	..	..	..	..	181,931	3,81,808	5,82,080	43,439
..	..	..	..	..	..	..	..	..	..	70,533	5,264
..	..	26,337	32,550	2,935	68,707	4,908	6,411	372,949	4,13,154	26,23,386	195,775
..	..	8,366	11,800	..	..	102,650	3,40,444	1,291,907	2,11,846	5,69,355	42,489
..	..	126,945	1,81,760	..	..	..	.	1,245,022	8,20,693	36,73,363	274,131
..	..	6,246	50,776	..	..	..	..	88	106	3,02,839	22,599
..	..	..	..	..	..	....	..	96 886	50,374	9,5[illegible],177	71,506
..	..	11,808	42,692	..	..	..	..	.	..	42,692	3 186
..	..	.	..	..	..	..	..	17,094	21,721	26,171	1,953
..	..	..	..	..	..	..	..	404,983	11,88,214	12,92,962	96,490
..	..	1,364	8,890	..	..	..	..	27,202	1,36,458	3,34,072	24,931
..	..	..	..	..	..	..	..	..	..	8,112	605
..	..	..	..	4,850	1,23,965	..	..	224,142	2,92,657	11,66,422	87,046
4,854	1,22,541	105,996	5,72,404	200	830	..	..	39,605	51,885	10,73,710	80,128
..	..	56,349	53,008	888	9,190	..	..	663,263	13,82,390	21,62,286	161,365
4,854	1,22,541	349,579	9,69,429	8,873	2,02,692	107,558	3,46,855	4,565,0 2	49,51,306	1,48,86,160	1,110,907

Clays.

There was an increase in the recorded production of clays, which rose from 129,177 tons valued at Rs. 2,65,572 (£19,819) in 1927 to 185,576 tons valued at Rs. 4,24,180 (£31,655) in 1928.

TABLE 37.—*Production of Clays in India during the year 1928.*

—	1928.		
	Quantity.	Value (£1=Rs. 13·4).	
	Tons.	Rs.	£
Bengal	44,149	87,759	6,549
Bihar and Orissa	24,771	1,84,863	13,796
Burma	26,865	37,584	2,805
Central India	864	2,926	218
Central Provinces	60,219	57,569	4,296
Gwalior	743	5,018	375
Kashmir	958	1,105	82
Madras	17,366	1,893	141
Mysore	8,957	43,914	3,277
Rajputana	684	1,549	116
Total	185,576	*4,24,180*	*31,655*

Copperas.

The production of sulphate of iron in Ladakh, Kashmir State, fell from 8 cwts. valued at Rs. 15 (£1) in 1927, to 3·3 cwts. valued at Rs. 6 (£0·4) in 1928.

Corundum.

The production of corundum in the Salem district, Madras, amounted to 21 tons valued at Rs. 2,780 (£207). There was no production reported from the Bhandara district of the Central Provinces. (*See* also under "Ruby, Sapphire and Spinel".)

Fuller's Earth.

The reported production of Fuller's earth rose from 2,718 tons in 1927 to 3,394 tons in 1928. Bikaner and Mysore were chiefly responsible for the increased figure, but the returns from the latter are not always trustworthy owing to the illiteracy of the workers. Jodhpur showed a slight increase.

TABLE 38.—*Quantity and value of Fuller's Earth produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Central Provinces—						
Jubbulpore	35	173	13	76	374	28
Mysore	214	539	40	457	559	42
Rajputana—						
Bikaner State	1,469	9,335	696	1,836	11,020	822
Jaisalmer State	23	345	26	25	351	26
Jodhpur State	977	12,222	912	1,000	12,509	934
Total	2,718	*22,614*	*1,687*	3,394	*24,813*	*1,852*

Garnet.

The production of garnet sand amounted to 480 tons valued at Rs. 1,200 (£90) in 1928, against 285 tons valued at Rs. 712 (£53) in 1927. The whole of the production was reported from the Tinnevelly district, Madras.

Gypsum.

There was a decided increase in the output of gypsum from 38,105 tons valued at Rs. 89,809 (£6,702) in 1927 to 59,050 tons valued at Rs. 1,46,322 (£10,919) in 1928. The effect of gypsum in small quantities upon crops —a common application is 2 maunds to the acre—is said to be remarkable, and its usefulness to the monsoon crops of southern Bihar has been experimentally demonstrated.[1] The Department of Agriculture, Bihar and Orissa, is importing annually increasing amounts of gypsum from Jamsar in Bikaner. This experimental

[1] D. Clouston. Review of Agricultural Operations in India, 1924-25, page 52

work may, therefore, ultimately result in a demand from agricultural districts for gypsum.

TABLE 39.—*Quantity and value of Gypsum produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Baroda State	..	..	..	257	1,531	114
Kashmir State	..	..	..	82	86	6
Punjab—						
Jhelum	4,112	7,065	527	17,971	28,848	2,153
Rajputana—						
Bikaner State	23,837	54,991	4,104	25,597	74,873	5,588
Jaisalmer State	156	1,003	75	143	859	64
Jodhpur State	10,000	26,750	1,996	15,000	40,125	2,994
Total	38,105	*89,809*	*6,702*	59,050	*1,46,322*	*10,919*

Kyanite (see "**Miscellaneous Refractory Materials**").

Miscellaneous refractory materials.

The production of kyanite amounted to 2,241 tons valued at Rs. 33,615 (£2,509) of which 1,896 tons were produced from the Lapso Hill mines in Kharsawan State and 345 tons from Mr. E. O. Murray's Ghagidih mines in the Singhbhum district, Bihar and Orissa. The production of quartzite, including quartz-kyanite-schist and quartz-mica-schist, in Bihar and Orissa, amounted to 29,184 tons valued at Rs. 51,611 (£3,851), of which 26,860 tons represent the production of quartzite, 1,733 tons the production of quartz-kyanite-schist and 591 tons the production of quartz-mica-schist. A small output of quartzite, amounting to only 4 cwts., was reported from the Mysore State. The total production of kyanite and quartzite, including the schists, in India amounted to 31,425 tons valued at Rs. 85,226 (£6,360) in 1928 against 17,571 tons valued at Rs. 77,760 (£5,803) in 1927.

Ochre.

There was a further increase in the production of ochre, which amounted to 6,153 tons valued at Rs. 52,975 (£3,953) in 1928 against 3,472 tons valued at Rs. 27,477 (£2,051) in 1927. This increase is chiefly due to the output of 2,231 tons from the Panna State in Central India, from which there had been no production in the previous year.

TABLE 40.—*Quantity and value of Ochre produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Central India	760	2,822	211	3,499	26,878	2,006
Central Provinces	1,026	9,533	711	847	7,915	591
Gwalior	316	4,162	311	817	10,252	765
Madras	350	4,750	354	325	4,500	336
Rajputana	323	721	54	317	688	51
United Provinces	697	5,489	410	348	2,742	204
Total	3,472	*27,477*	*2,051*	6,153	*52,975*	*3,953*

Quartzite (see "**Miscellaneous Refractory Materials**").

Serpentine.

The production of serpentine in the Skardu *tahsil*, Kashmir State, amounted to 1·8 tons valued at Rs. 75 (£6) in 1928 against *nil* in the previous year.

Soda.

Eleven tons of soda valued at Rs. 537 (£40) were produced in the Ladakh *tahsil*, Kashmir State. The same quantity was produced in the previous year. Salt, consisting for the greater part of sodium carbonate, sodium bicarbonate and sodium chloride, used to be obtained by evaporation from the waters of the Lonar Lake in the Buldana district of the Central Provinces. It was known under the general name of *trona* or *urao*, for which there is no suitable equivalent in English. The total amount of *trona* extracted in 1926 was 100 tons, the value of which was estimated at Rs. 3,000 (£224); in 1927 there was no

production, as the company working the concession had gone into liquidation. There was a production of 1·8 tons of crude soda (*rasi*) valued at Rs. 50 (£3·7) in Datia State, Central India, in the year under review.

Steatite.

There was a slight increase in the production of steatite, which rose from 5,053 tons valued at Rs. 1,04,732 (£7,816) in 1927 to 5,539 tons valued at Rs. 1,30,070 (£9,706) in 1928.

TABLE 41.—*Quantity and value of Steatite produced in India during the years 1927 and 1928.*

—	1927.			1928.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa—						
Mayurbhanj	67	6,300	470	80	7,300	545
Santhal Parganas	110	1,654	123	..	..	..
Seraikela	19	1,060	79	15	840	63
Singhbhum	271	16,839	1,257	346	7,706	575
Central India—						
Bijawar State	202	1,920	143	162	6,600	493
Central Provinces—						
Bhandara	250	10,000	746	..	..	..
Jubbulpore	870	10,960	818	1,284	23,281	1,737
Madras—						
Nellore	87	3,917	292	49	2,331	174
Salem	795	19,438	1,451	164	6,940	518
Mysore	68	204	15	88	264	20
Rajputana—						
Jaipur State	2,206	30,000	2,239	3,228	65,849	4,912
United Provinces—						
Hamirpur	8	760	57	119	8,629	644
Jhansi	100	1,680	126	4	330	25
Total	**5,053**	***1,04,732***	***7,816***	**5,539**	***1,30,070***	**9,706**

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 42.—*Statement of Mineral Concessions granted during the year 1928.*

AJMER-MERWARA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term
Ajmer	(1) M. Abdul Ghani & Co., Nasirabad.	Mica	P. L.	2·8	15th March 1928.	1 year.
Do.	(2) Mr. Nussarwanji D. Contractor, Ajmer.	Mica, beryl and acquamarine.	P. L.	2·0	21st March 1928.	Do.
Do.	(3) Mr. E. P. Thomas, Mining Engineer, Ajmer.	Mica	P. L. (renewal).	8·2	7th April 1928.	Do.
Do.	(4) Messrs. Radha Kishen Kanhya Lal, Nasirabad.	Do.	P. L.	0·8	12th April 1928.	Do.
Do.	(5) Mr. P Kishen Lal Sharma, Contractor, Beawar.	Do.	P. L.	3·5	1st June 1928	Do.
Do.	(6) Mr. L. Chhagan Lal, Nasirabad.	Do.	P. L.	2·8	11th June 1928.	Do.
Do.	(7) Do.	Do.	P. L.	1·9	7th July 1928	Do.
Do.	(8) Mr. Mohammed Ali Chishti, Beawar.	Do.	P. L.	2·8	17th September 1928.	Do.
Do.	(9) Mr. Govardhan Lal Rathi, Nasirabad.	Do.	P. L.	1·2	6th August 1928.	Do.
Do.	(10) Messrs. Abdul Ghani & Co., Nasirabad.	Do.	P. L. (renewal).	2·2	12th January 1928.	Up to 31st March 1929.
Do.	(11) Do.	Do.	P. L.	1·8	25th October 1928.	1 year.
Do.	(12) Do.	Do.	P. L.	0·3	31st October 1928.	Do.
Do.	(13) Mr. Dhiraj Lal, Nasirabad.	Do.	P. L. (renewal).	2·4	15th January 1928.	Up to 10th October 1929.
Do.	(14) Messrs. G. K. Soniji & Co., Ajmer.	Do.	M. L.	20	17th February 1928.	7 years.
Do.	(15) Mr. L. Goverdhan Lal Rathi, Nasirabad.	Do.	M. L.	Not stated.	29th September 1928.	2 years.
Beawar	(16) M. Mohammed Fazil.	Do.	P. L.	3·7	24th January 1928.	1 year.
Do.	(17) Do.	Do.	P. L.	0·4	Do.	Do.
Do.	(18) Do.	Do.	P. L. (renewal).	2·54	31st January 1928.	Do.
Do.	(19) M. Mohammed Hayat.	Do.	P. L.	3·9	15th March 1928.	Do.
Do.	(20) Do.	Do.	P. L.	1·07	10th April 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

AJMER-MERWARA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Beawar .	(21) Mohammed Ali Chishti.	Mica . . .	P. L. .	7·5	13th June 1928.	1 year.
Do. .	(22) Mohammed Hayat,	Do. . . .	P. L. .	1·9	6th July 1928	Do.
Do. .	(23) Do. .	Do. . . .	P. L. .	·05	Do. .	Do.
Do. .	(24) Mr. Krishna Mool Chand Kapoor, Ajmer.	Do. . . .	P. L. .	6·56	11th July 1928.	Do.
Do. .	(25) Do. .	Do. . . .	P. L. .	1·65	Do.	Do.
Do. .	(26) The General Manager, Rajputana Minerals Company, Limited, Ajmer.	Do. . . .	M. L. (renewal).	7·04	13th March 1928.	10 years.

ASSAM.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cachar .	(27) The Burmah Oil Company, Limited.	Mineral oil . .	P. L. (renewal).	360	4th January 1928.	2 years.
Do. .	(28) Baddarpur Oil Company.	Do. . .	P. L. (renewal).	1,388·8	1st November 1928.	Do.
Khasi and Jaintia Hills.	(29) The Khasia Sillimanite Company, Limited.	Sillimanite, Corundum, etc.	M. L. .	1,920	17th December 1928.	30 years.
Do. .	(30) Garo Hills Corporation, Limited.	Coal . . .	P. L. (renewal).	2,880	21st August 1928.	3 years.
Lakhimpur .	(31) The Burmah Oil Company, Limited.	Mineral oil	P. L. (renewal).	192,000	2nd November 1928.	1 year.
Do. .	(32) Assam Oil Company, Limited.	Do. . .	P. L. (renewal).	5,120	30th March 1928.	Do.
Do. .	(33) Do. .	Do. . .	P. L. (renewal).	3,968	12th May 1928.	Do.
Do. .	(34) Do. .	Do. . .	P. L. (renewal).	9,792	30th June 1928.	2 years.
Do. .	(35) Do. .	Coal . . .	P. L. (renewal).	3,616	8th October 1928.	1 year.
Do. .	(36) Do. .	Mineral oil . .	P. L. (renewal).	1,792	25th July 1928.	Do.
Do. .	(37) The Burmah Oil Company, Limited.	Do. . .	P. L. .	40,960	30th March 1928.	2 years.
Do. .	(38) Assam Oil Company, Limited.	Do. . .	M. L. (renewal).	2,624	15th October 1928.	25 years.
Sadiya Frontier Tract.	(39) Do. .	Do. . .	P. L (renewal).	2,240	19th December 1928.	1 year.
Sibsagar .	(40) The Burmah Oil Company, Limited.	Do. . .	P. L. .	614,400	10th August 1928.	1 year.
Sylhet .	(41) Do. .	Do. . .	P. L. .	3,425·28	14th September 1928.	2 years.
Do. .	(42) Do. .	Do. . .	P. L. .	9,184	5th March 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BALUCHISTAN.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kalat .	(43) The Burmah Oil Co., Ltd., of Scotland.	Mineral oil .	P. L. (renewal).	3,200	1st September 1927.	2 years.
Do. .	(44) Messrs. Sorabjee and Sons of Quetta.	Coal and coal dust.	M. L. .	80	1st September 1928.	30 years.

BENGAL.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chittagong .	(45) The Burmah Oil Co., Ltd.	Natural Petroleum	P. L. .	4,000	9th March 1928.	1 year.
Chittagong Hill Tracts.	(46) Do. .	Mineral oil .	P. L. (renewal)	4,313·6	8th October 1928.	Do.

BIHAR AND ORISSA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Santal Parganas.	(47) Babu Bhudar Chandra De.	Coal . . .	M. L. .	1	1st November 1927.	2 years.
Singhbhum.	(48) The Tata Iron and Steel Co.	Chromite . .	P. L. (renewal).	1,491·20	4th February 1928.	6 months.
Do. .	(49) Babu Mangilal Marwari.	Iron-ore and manganese.	P. L. .	2,944	19th March 1928.	1 year.
Do. .	(50) Babu Dwarkadas Agarwalla.	Do. .	P. L. .	522·20	25th February 1928.	Do.
Do. .	(51) Do. .	Manganese .	P. L. (renewal).	848	6th May 1928	6 months.
Do. .	(52) Babu Arjun Ladha.	Do. . .	P. L. .	742·40	17th March 1928.	1 year.
Do. .	(53) Babu Warjung Harji.	Manganese and yellow ochre.	P. L. .	30·00	8th January 1929.	Do.
Do. .	(54) Do. .	Manganese and red ochre.	P. L. .	379·25	Do. .	Do.

BOMBAY.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Belgaum .	(55) Rao Sahib C. Manickam.	Manganese . .	M. L. .	3.20	1st January 1928.	10 years.
Do. .	(56) Mr. A. N. Peston Jamas.	Bauxite . .	P. L. .	60	15th October 1928.	5½ months.
Do. .	(57) Messrs. Boyce & Co.	Manganese . .	P. L. .	Not stated	18th October 1928.	1 year.
Do. .	(58) Messrs. Lalan & Co.	Do. . .	P. L. .	556	20th December 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BOMBAY—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Belgaum .	(59) Mrs. T. C. Boyce	Manganese . .	P. L. .	Not stated	18th October 1928.	1 year.
Do. .	(60) Mr. A. N. Peston Jamas.	Do. . .	P. L. .	150	30th October 1928.	Do.
Do. .	(61) Mr. M. S. Karaka	Do. . .	P. L. .	80	Do. .	Do.
Kanara .	(62) Messrs. Lalan & Co.	Do. . .	P. L. .	888	26th May 1928.	Do.
Do. .	(63) The Kanara Mining Syndicate.	Do. . .	P. L. .	388	5th April 1928.	Do.
Do. .	(64) Do. .	Do. . .	P. L. .	536	14th December 1928.	Do.
Do. .	(65) Do. .	Do. . .	P. L. .	351	15th August 1928.	Do.

BURMA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Akyab .	(66) Mr. J Ezekiel .	Natural Petroleum (including natural gas).	P. L. .	3·2	27th June 1928.	2 years.
Do. .	(67) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. . (renewal).	1,177·6	22nd April 1928.	1 year.
Do. .	(68) Messrs. The Burmah Oil Co., Ltd.	Do. .	P. L. . (renewal).	4,480	28th July 1928.	Do.
Amherst .	(69) Dr. K. S. Kanga	All minerals except oil.	P. L. .	320	17th September 1928.	Do.
Do. .	(70) A. C. Martin .	Do. .	P. L. .	640	8th March 1928.	Do.
Do. .	(71) L. Ah Choy .	Do. .	P. L. .	1,280	28th July 1928.	Do.
Do. .	(72) S. S. Halkar .	Do. .	P. L. .	262·4	28th May 1928.	Do.
Do. .	(73) Chew Whee Shain	Do. .	P. L. . (renewal).	2,240	17th January 1928.	9½ months.
Do. .	(74) A. C. Martin .	Do. .	P. L. . (renewal).	1,280	21st January 1928.	1 year.
Henzada .	(75) Messrs. Steel Bros. & Co., Ltd., Managing Agents for I. B. P. Co., Ltd.	Mineral oil .	P. L. .	3,200	19th December 1928.	2 years.
Lower Chindwin.	(76) U Po Tin . .	Natural Petroleum (including natural gas).	P. L. .	134·4	29th May 1928.	Do.
Do. .	(77) The Burmah Oil Co., Ltd.	Do. .	P. L. . (renewal).	2,560	12th November 1927.	1 year.
Do. .	(78) Do. .	Do. .	P. L. . (renewal).	640	24th January 1928.	Do.

P. L. = *Prospecting Licence.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Lower Chindwin.	(79) Mr. Lawrence Dawson.	Natural Petroleum (including natural gas).	P. L. (renewal).	1,196·8	5th February 1928.	1 year
Magwe .	(80) British Burma Petroleum Co.	Petroleum . .	P. L. .	15,360	11th April 1928.	2 years.
Do. .	(81) Indo-Burma Petroleum Co.	Do. . .	P. L. .	320	16th April 1929.	Do.
Do. .	(82) British Burma Petroleum Co.	Do. . .	P. L. .	1,920	20th April 1928.	Do.
Do. .	(83) U. Mo Thaung .	Do. . .	P. L. .	640	21st June 1928.	Do.
Do. .	(84) British Burma Petroleum Co.	Do. . .	P. L. .	640	23rd July 1928.	Do.
Do. .	(85) Mr. Abdul Rahman.	Natural Petroleum (including natural gas).	P. L. (renewal).	1,280	27th July 1928.	1 year.
Do. .	(86) Burma Oil Co. .	Do. .	P. L. (renewal).	640	2nd September 1928.	Do.
Do. .	(87) British Burma Petroleum Co.	Do. .	P. L. (renewal).	70·4	26th August 1928.	Do.
Mergui .	(88) Ma Tin . .	Tin and allied minerals.	P. L. .	652·8	3rd February 1928.	Do.
Do. .	(89) Mr. George Everard Anderson.	Do. .	P. L. .	723·3	27th January 1928.	Do.
Do. .	(90) Mr. Lim Shain .	All kinds of minerals except mineral oil.	P. L. .	582·8	5th December 1928.	Do.
Do. .	(91) Lee Quee Chee .	Tin. . . .	P. L. .	1,619·2	26th January 1928.	Do.
Do. .	(92) Do. .	Do. .	P. L. .	857·6	Do.	Do.
Do. .	(93) Do. .	Do. .	P. L. .	1,619·2	Do.	Do.
Do. .	(94) Mr. Geo. W. Bowden.	Tin and allied minerals.	P. L. .	499·2	24th July 1928.	Do.
Do. .	(95) Messrs. Tavoy Prospectors.	All minerals except oil.	P. L. .	1,996·8	4th January 1928.	Do.
Do. .	(96) Lee Quee Chee .	Tin and allied minerals.	P. L. .	1,992·8	24th February 1928.	Do.
Do. .	(97) Do. . .	Tin and allied minerals except mineral oil.	P. L. .	1,847·2	Do.	Do.
Do. .	(98) Mr. Kapursingh .	Tin. . . .	P. L. .	851·2	21st April 1928.	Do.
Do. .	(99) Ah Shee . .	Tin-ore . .	P. L. .	416	17th March 1928.	Do.
Do. .	(100) Ah Khoon .	Tin and allied metals.	P. L. .	140·8	15th June 1928.	Do.
Do.	(101) Maung Po .	Tin and allied minerals.	P. L. .	326·4	18th April 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—contd.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(102) Leong Ah Foo .	Tin-ore . .	P. L. .	204·8	2nd May 1928.	1 year.
Do. .	(103) Mr. W. R. Coleridge Beadon.	Do. . .	P. L. .	160	Do. .	Do.
Do. .	(104) Do. .	Do. . .	P. L. .	160	10th May 1928.	Do.
Do. .	(105) Mr. R. C. N. Twite.	Tin and allied minerals.	P. L. .	256	21st May 1928.	Do.
Do. .	(106) Mr. George Everard Anderson.	Do. .	P. L. .	601·6	18th May 1928.	Do.
Do. .	(107) Ah Yee . .	Tin	P. L. .	640	7th January 1928.	Do.
Do. .	(108) Ah Khoon .	All kinds of minerals except oil.	P. L. .	1,184	18th April 1928.	Do.
Do. .	(109) Mr. B. B. Jubb	Tin ore and other allied metals.	P. L. .	435·2	17th March 1928.	Do.
Do.	(110) Mr. S. Warwick Smith.	All minerals other than mineral oil.	P. L. .	89·6	7th January 1928.	Do.
Do. .	(111) Ma Kyin Mya & Ma Lin.	Tin and allied minerals.	P. L. .	460·8	18th April 1928.	Do.
Do. .	(112) Mr. Joo Seng .	All minerals except oil.	P. L. .	128	2nd August 1928.	Do.
Do. .	(113) Do. .	Do. .	P. L. .	140·8	27th July 1928.	Do.
Do. .	(114) Mr. Kwee Ya .	Tin	P. L. .	128	21st April 1928.	Do.
Do. .	(115) Maung San Dun	Do.	P. L. .	19·2	21st April 1928.	Do.
Do. .	(116) Maung E. Gyi .	Tin and allied minerals except mineral oil.	P. L. .	358·4	20th August 1928.	Do.
Do. .	(117) Tan Boon Hein.	Tin and allied minerals.	P. L. .	249·6	21st April 1928.	Do.
Do.	(118) Mr. J. I. Milne .	Tin-ore . .	P. L. .	281·6	3rd May 1928.	Do.
Do. .	(119) Mr. A. J. Beale .	Tin	P. L. .	1,184	27th August 1928.	Do.
Do. .	(120) Messrs. Holmes & Morgan.	All minerals except oil.	P. L. .	211·2	27th August 1928.	Do.
Do.	(121) Mr. J. I. Milne .	Tin-ore . .	P. L. .	332·8	10th September 1928.	Do.
Do. .	(122) Mr. W. R. Coleridge Beadon.	Do. . .	P. L. .	262·4	25th June 1928.	Do.
Do. .	(123) Mr. A. S. Mahomed.	Tin-ore and other allied metals.	P. L. .	300·8	17th August 1928.	Do.

M. L. = Mining Lease.

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(124) Tan Eik Kun .	Tin-ore . .	P. L. .	262·4	27th June 1928.	1 year.
Do. .	(125) Maung Maung .	Tin and Wolfram.	P. L. .	620·8	9th October 1928.	Do.
Do .	(126) Eng Tain Leong	Tin-ore . .	P. L. .	64	2nd June 1928.	Do.
Do. .	(127) Tan Eik Kun .	Do. . .	P. L. .	332·8	27th June 1929.	Do.
Do. .	(128) Tan Sine Shin .	Tin and allied metals.	P. L. .	217·6	8th June 1928.	Do.
Do. .	(129) Maung San Dun	Tin . . .	P. L. .	998·4	21st August 1928.	Do.
Do. .	(130) Maung Po .	Do. . . .	P. L. .	128	22nd December 1928.	Do.
Do. .	(131) Messrs. Wightman & Co. (of Rangoon), Ltd.	All minerals other than petroleum and precious stones.	P. L. .	4,934·4	Do. .	Do.
Do. .	(132) Do. .	Do. .	P. L. .	1,171·2	18th October 1928.	Do.
Do. .	(133) Mr. S. Warwick Smith.	All minerals except mineral oil.	P. L. .	110·8	7th September 1928.	Do.
Do. .	(134) Mr. B. B. Jubb	Tin . . .	P. L. .	102·4	10th September 1928.	Do.
Do. .	(135) Mr. Leslie R. Beale.	Tin and allied minerals except oil.	P. L. .	472·6	8th September 1928.	Do.
Do. .	(136) Mr. Joo Seng .	Tin . . .	P. L. .	472·6	5th December 1928.	Do.
Do. .	(137) Ah Shee . .	Tin-ore . .	P. L. .	288	18th October 1928.	Do.
Do. .	(138) Maung Pan On	Tin and allied minerals.	M. L. .	70·4	20th January 1928.	21 years.
Do. .	(139) Mr. E. Maxwell Lefroy.	All minerals except precious stones and mineral oil.	M. L. .	428·8	16th January 1928.	30 years.
Do. .	(140) Messrs. Beadon and Doupe.	Tin and allied minerals.	M. L. .	2,252·8	1st March 1928.	Do.
Do. .	(141) Maung San Dun	Tin-ore . .	M. L. .	185·6	1st June 1928.	Do.
Do. .	(142) Ma Tin . .	Tin and allied minerals.	M. L. .	358·4	Do. .	Do.
Do. .	(143) Tan Sine Shin .	Do. .	M. L. .	281·6	1st August 1928.	Do.
Do. .	(144) Mr. P. B. O. Watson.	Do. .	M. L. .	588·8	1st October 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(145) Mr. J. I. Milne .	Tin-ore . .	M. L. .	1,888	1st June 1928.	30 years.
Do. .	(146) Mr. E. Maxwell Lefroy.	Tin and allied minerals.	M. L. .	838·4	16th January 1928.	Do.
Do. .	(147) Mr. E. Ahmed .	Wolfram, tin and other allied metals.	M. L. .	441·6	1st November 1929.	15 years.
Do. .	(148) Lim Oo Ghine .	Tin-ore . .	M. L.	204·8	1st November 1928.	30 years.
Do. .	(149) Ma Kyin Mya & Ma Lin.	Tin ore and allied minerals except mineral oil.	M. L.	25·6	24th October 1924.	Do.
Do. .	(150) Messrs. Mergui Tin Ltd.	Tin and gold .	P. L. . (renewal).	512	10th January 1928.	1 year.
Do. .	(151) Mr. M. A. Musaji	Tin and allied minerals except mineral oil.	P. L. . (renewal).	313·6	1st February 1928.	Do.
Do. .	(152) U. Shwe Yun .	Do. .	P. L. . (renewal).	256	4th March 1928.	Do.
Do. .	(153) Ma Tin . .	Do. .	P. L. . (renewal).	716·8	15th March 1928.	Do.
Do. .	(154) Mr. Gul Mohamed	Do. .	P. L. . (renewal).	576	28th March 1928.	Do.
Do. .	(155) Mr. A. E. Ahmed	Tin-ore and other allied metals except mineral oil.	P. L. . (renewal).	486·4	22nd February 1928.	Do.
Do. .	(156) Tan Eik Kun .	Tin and allied minerals except mineral oil.	P. L. . (renewal).	518·4	5th April 1928.	Do.
Do. .	(157) Mr. Leslie R. Beale.	Do. .	P. L. . (renewal).	1,568	4th May 1928	Do.
Do. .	(158) Eu Gwan Kyin .	Tin . . .	P. L. . (renewal).	1,580 8	Do. .	Do.
Do. .	(159) Major J. W. Newbery.	Do. . . .	P. L. . (renewal.)	224	31st March 1928.	Do.
Do. .	(160) Messrs. Morgan and Holmes.	Tin and allied minerals except mineral oil.	P. L. . (renewal).	985·6	2nd June 1928.	Do.
Do. .	(161) Mr. E. B. Milne.	All minerals except mineral oil.	P. L. . (renewal).	716·8	4th June 1928.	Do.
Do. .	(162) Eu Gwan Kyin .	Tin . . .	P. L. . (renewal).	812·8	22nd June 1928.	Do.
Do. .	(163) Mr. M. A. Musaji	Tin and allied minerals except mineral oil.	P. L. . (renewal).	281·6	20th July 1928.	Do.
Do. .	(164) Messrs. Mayan Chaung Alluvials, Ld.	Do. .	P. L. . (renewal).	294·4	Do. .	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(165) Mr. Joo Seng .	Tin and allied minerals except mineral oil.	P. L. . (renewal).	486·4	22nd August 1928.	1 year.
Do. .	(166) Messrs. Mayan Chaung Alluvials, Ld.	Do. .	P. L. . (renewal).	435·2	16th August 1928.	Do.
Do. .	(167) Do. .	Do. .	P. L. . (renewal).	1,792	19th September 1928.	Do.
Do. .	(168) Mohamed Ismail	Do. .	P. L. . (renewal).	857·6	7th October 1928.	Do.
Do. .	(169) Maung E. Gyi .	Do. .	P. L. . (renewal).	460·8	23rd September 1928.	Do.
Do. .	(170) Mr. G. H. Hand	Do. .	P. L. . (renewal).	780·8	8th October 1928.	Do.
Do. .	(171) Mr. R. A. Park .	Tin . . .	P. L. . (renewal).	857·6	16th November 1928.	Do.
Do. .	(172) Mr. G. H. Hand	Tin-ore . .	P. L. . (renewal).	627·2	31st December 1928.	Do.
Minbu .	(173) U Maung Maung	Natural Petroleum	P. L. .	288	21st March 1928.	Do.
Myingyan .	(174) The Yenangyaung oil-field, Southern Extension, Ltd.	Mineral oil . .	P. L. . (renewal).	1,280	27th September 1928.	Do.
Northern Shan States.	(175) Hkun Pan Sing, Sawbwa of Taungpeng State.	Lead and silver .	P. L. .	371·84	14th November 1928.	Do.
Do. .	(176) Do. .	Iron-ore . .	P. L. .	225·92	Do. .	Do.
Do. .	(177) A. B. Oberlander	Lead and silver .	P. L. . (renewal).	1,920	15th February 1928.	Do.
Do. .	(178) Messrs. The Burma Corporation, Ltd.	Iron-ore . .	P. L. . (renewal).	121·6	11th May 1928.	Do.
Do. .	(179) Do. .	Do. . .	P. L. . (renewal).	198·4	5th June 1928.	Do.
Pakokku .	(180) Maung Po Shwe	Natural Petroleum	P. L. .	640	11th January 1928.	Do.
Do .	(181) Burmah Oil Co., Ld.	Do. .	P. L. .	1,920	23rd May 1928.	Do.
Do. .	(182) Maung Po Shwe	Do. .	P. L. . (renewal).	96	21st November 1927.	Do.
Do. .	(183) Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. . (renewal).	2,400	12th February 1928.	Do.
Do. .	(184) Burmah Oil Co., Ltd.	Do. .	P L. . (renewal).	800	7th November 1928.	Do.
Salween .	(185) U. Ohoon .	All minerals except mineral oil.	P. L. . (renewal).	2,560	14th December 1927.	Do.

P. L. = *Prospecting Licence.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Shwebo .	(186) Messrs. The Indo-Burma Petroleum Co., Ltd.	Natural Petroleum	P. L. . (renewal).	5,113·6	12th March 1928.	1 year.
Southern Shan States.	(187) United Excelsior Mines, Ltd.	All except oil .	P. L. .	480	1st June 1928	Do.
Do. .	(188) Tan Po Yin	Do. .	M. L. .	89·6	1st August 1928.	5 years.
Do. .	(189) Fairweather Richards & Co.	Do. .	P. L. .	160	31st December 1928.	1 year.
Do. .	(190) H. A. S. H. Cassim & Bros.	Do. .	P. L. . (renewal).	2,304	15th October 1927.	Do.
Do .	(191) Tan Po Yin	Do.	P. L. (renewal).	640	3rd August 1928.	Do.
Do.	(192) Lawksank Sawbwa.	Do.	P. L. (renewal).	12,000	1st November 1928.	Do.
Tavoy	(193) Tavoy Tin Dredging Corporation, Ltd.	Tin and wolfram	P. L.	448	11th September 1928.	Do.
Do.	(194) Mr. H. C. Flanders.	Do.	P. L.	960	26th April 1928.	Do.
Do.	(195) Mr. A. W. Ross	Do.	P. L.	224	18th January 1928.	Do.
Do.	(196) Messrs. Crisp & Co.	Do. .	P. L. .	556·8	21st January 1928.	Do.
Do. .	(197) The Anglo-Burma Tin Co., Ltd.	Do. .	P. L. .	57·6	10th January 1928.	Do.
Do. .	(198) Do. .	Do. .	P. L. .	102·4	Do. .	Do.
Do. .	(199) Do. .	Do. .	P. L. .	25·6	Do. .	Do.
Do. .	(200) Daw Ye . .	Do. .	P. L. .	640	11th September 1928.	Do.
Do. .	(201) Do. . .	Do. .	P. L. .	454·4	5th January 1928.	Do.
Do. .	(202) Khoo Sein Shan	Do. .	P. L. .	729·6	24th March 1928.	Do.
Do. .	(203) Tavoy Tin Dredging Corporation, Ltd.	Tin . . .	P. L. .	1·92	23rd July 1928.	Do.
Do. .	(204) Khoo Tun Byan	Tin and wolfram	P. L. .	1,145·6	9th February 1928.	Do.
Do. .	(205) Khoo Tun Byan	Do. .	P. L. .	889·6	29th February 1928.	Do.
Do. .	(206) Mr. R. Ady .	Do. .	P. L. .	4,096	25th August 1928.	Do.
Do. .	(207) Crisp & Co. .	Do. .	P. L. .	249·6	1st May 1928	Do.
Do. .	(208) Ong Hoe Kyin .	Do. .	P. L. .	864	20th March 1928.	Do.

P. L. = *Prospecting Licence.* M. L. = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(209) The Consolidated Tin Mines of Burma, Ltd.	Tin and wolfram	P. L. .	38·4	30th March 1928.	1 year.
Do. .	(210) Mr. A. J. Robertson.	Do. .	P. L. .	388	7th November 1928.	Do.
Do. .	(211) Kim Shwe .	Do. .	P. L. .	697·6	16th August 1928.	Do.
Do. .	(212) The Anglo-Burma Tin Co., Ltd.	Do. .	P. L. .	2,284·8	Do. .	Do.
Do. .	(213) The Consolidated Tin Mines of Burma, Ltd.	Do. .	P. L. .	25·6	9th July 1928	Do.
Do. .	(214) Eu Pola Bros. .	Do .	P. L. .	377·6	4th July 1928	Do.
Do. .	(215) Do. .	Do. .	P. L. .	595·2	27th August 1928.	Do.
Do. .	(216) Khoo Sein Shan	Do. .	P. L. .	428·8	27th November 1928.	Do.
Do. .	(217) Mr. P. N. Illingworth.	Do. .	P. L. .	1,836·8	27th June 1928.	Do.
Do. .	(218) Mr. D. R. Bowrie	Do. .	P. L. .	800	10th December 1928.	Do.
Do. .	(219) The Consolidated Tin Mines of Burma, Ld.	Do. .	P. L. .	25·6	14th November 1928.	Do.
Do. .	(220) Mr. S. N. Dutt .	Do. .	P. L. .	499·2	4th August 1928.	Do.
Do. .	(221) Mr. J. J. A. Page	Do. .	P. L. .	435·2	16th November 1928.	Do.
Do. .	(222) U. Kyaing .	Do. .	P. L. .	640	12th December 1928.	Do.
Do. .	(223) Maung Ngwe Thi.	Do. .	M. L. .	601·6	1st March 1928.	30 years.
Do. .	(224) Messrs. Newbery and Ward.	Do. .	P. L. . (renewal).	179·2	9th August 1927.	1 year.
Do. .	(225) Eu Pola Bros. .	Do. .	P. L. . (renewal).	512	26th November 1927.	Do.
Do. .	(226) Mrs. S. Wellington.	Do. .	P. L. . (renewal).	640	4th January 1928.	Do.
Do. .	(227) Mr. R. C. N Twite.	Do. .	P. L. . (renewal).	435·2	27th January 1928.	Do.
Do. .	(228) Quah Hun Cheong.	Do. .	P. L. . (renewal).	275·2	3rd February 1928.	6 months.
Do. .	(229) The Tavoy Rubber Co., Ltd.	Do. .	P. L. . (renewal).	595·2	12th October 1927.	1 year.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(230) The Tavoy Rubber Co., Ltd.	Tin and wolfram	P. L. (renewal)	12·8	3rd December 1927.	1 years.
Do. .	(231) Mr. A. W. Ross	Do. .	P. L. . (renewal).	780·8	3rd February 1928.	Do.
Do. .	(232) Quah Cheng Guan.	Do. .	P. L. . (renewal)	640	6th May 1928	Do.
Do. .	(233) The Consolidated Tin Mines of Burma, Ltd.	Do .	P. L. . (renewal).	569·6	11th June 1927.	2 years.
Do. .	(234) U. Maung Maung.	Do. .	P. L. . (renewal)	320	4th July 1928	1 year
Do .	(235) Tavoy Tin Dredging Corporation Ltd.	Do. .	P. L. . (renewal).	960	7th May 1928	Do.
Do. .	(236) The Khamaunghla Tavoy Tin, Ltd.	Do .	P. L. . (renewal).	108·8	26th May 1928.	Do.
Do. .	(237) Maung E. Zin .	Do. .	P. L. . (renewal).	723·2	20th August 1928.	Do.
Thayetmyo.	(238) Messrs. The Burmah Oil Co., Ltd.	Mineral oil . .	P. L. . (renewal).	1,676·8	8th January 1928.	Do.
Do. .	(239) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . . .	P. L. . (renewal).	8,960	9th February 1928.	Do.
Do. .	(240) Messrs. The Burmah Oil Co., Ltd.	Do. . .	P. L. . (renewal).	2,240	23rd March 1928.	Do.
Do. .	(241) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. . (renewal).	6,400	28th April 1928.	Do.
Do. .	(242) U Tun Aung Gyaw.	Do. . .	P. L. . (renewal).	486·4	12th June 1928.	Do.
Upper Chindwin.	(243) The Burmah Oil Co., Ltd.	Natural petroleum	P. L .	8,320	25th June 1928.	2 years.
Do.	(244) Messrs. Fairweather Richards & Co., Ltd.	Coal	P. L.	1,280	29th October 1928.	1 year.
Do.	(245) Do.	Do.	P. L.	1,827·2	29th October 1928.	Do.
Do.	(246) Do.	Do.	P. L.	3,686·4	Not stated	Do.
Do.	(247) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . . .	P. L. (renewal).	2,560	17th March 1928.	Do.
Do.	(248) Do.	Natural petroleum (including natural gas).	P. L. (renewal).	640	6th October 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat	(249) Messrs. Cheniram Jashraj.	Manganese . .	M. L. .	60	14th March 1928.	30 years.
Do. .	(250) Pandit Kripa Shankar.	Do. . .	M. L.	101	5th April 1928.	Do.
Do. .	(251) Mr. Amrit Lal P. Trivedi.	Do. . .	P. L. .	73	2nd April 1928.	1 year.
Do. .	(252) Mr. M. B. Marfatia.	Do. . .	P. L.	65	2nd February 1928.	Do.
Do. .	(253) Mr. Amrit Lal P. Trivedi.	Do. . .	M. L. .	23	9th June 1928.	30 years.
Do. .	(254) Messrs. B. P. Byramji and Company.	Do. . .	M. L. .	32	22nd September 1928.	5 years.
Do. .	(255) Pandit Kripa Shanker.	Do .. .	M. L. . (Supplementary).	90	20th April 1928.	Will expire with original lease.
Do. .	(256) Mr. Mangal Singh.	Do. . .	P. L. .	332	18th February 1928.	1 year.
Do. .	(257) The Central India Mining Co., Ltd.	Do. . .	M. L. . (Supplementary).	19	17th May 1928.	Do.
Do. .	(258) Mr. Amrit Lal P. Trivedi.	Do. . .	P. L. .	300	5th July 1928	Do.
Do. .	(259) Mt. Munnabai .	Do. . .	M. L. .	200	12th March 1928.	30 years.
Do. .	(260) Mr. Amrit Lal P. Trivedi.	Do. . .	P. L. .	6	2nd May 1928	1 year.
Do. .	(261) Seth Bhopat Rao.	Do. . .	M. L. .	6	18th October 1928.	10 years.
Do. .	(262) Mr. A. P. Trivedi	Do. . .	P. L. .	50	2nd February 1928.	1 year.
Do. .	(263) Mr. Amrit Lal P. Trivedi.	Do. . .	P. L. .	20	Do. .	Do.
Do. .	(264) Mt. Munnabai .	Do. . .	P. L. .	200	16th February 1928.	1 year.
Do. .	(265) Mr. P. N. Oke .	Do. . .	M. L. .	40	13th April 1928.	30 years.
Do. .	(266) Mr. Kanhaiyalal	Do. . .	M. L. .	31	15th May 1928.	5 years.
Do. .	(267) Mr. Amrit Lal P. Trivedi.	Do. . .	P. L .	30	2nd February 1928.	1 year
Do. .	(268) Mr. Chandanlal .	Do. . .	P. L .	82	14th August 1928.	Do.
Do. .	(269) Mr. Diwanchand Jiwar.	Do. . .	P. L. .	215	22nd November 1928.	Do
Do. .	(270. Pandit Kripashankar.	Do. . .	M. L. . (Supplementary).	10	20th April 1928.	Will expire with the original lease

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(271) Khan Sahib Mir Ahmadali.	Manganese . .	P. L. .	380	29th December 1928.	1 year.
Do. .	(272) Mr. B. V. Buti .	Do. . .	P. L. .	100	21st June 1928.	Do.
Do.	(273) Mohamad Nuruddin Khan.	Do. . .	P. L. .	4	23rd November 1928.	Do.
Do. .	(274) Mr. Amrit Lal P. Trivedi.	Do. . .	P. L. .	30	2nd February 1928.	Do.
Do. .	(275) Messrs. B. P. Byramji & Co.	Do. . .	M. L. .	5	18th June 1927.	5 years.
Do. .	(276) Mt. Munnabai .	Do. . .	P. L. .	121	22nd March 1928.	1 year.
Do. .	(277) Mr. M. B. Marfatia.	Do. . .	P. L. .	35	29th May 1928.	Do.
Do. .	(278) Mr. Amrit Lal P. Trivedi.	Do. . .	P. L. .	35	5th April 1928.	Do.
Do. .	(279) Mr. N Venkat Ramanna.	Do. . .	P. L. .	60	25th July 1928.	Do.
Do. .	(280) Mr. M. B. Marfatia.	Do. . .	P. L. .	33	23rd April 1928.	Do.
Do. .	(281) The C. P. M. O. Co., Ltd.	Do. . .	M. L. . (Supplementary).	37	28th November 1928.	Will expire with the original lease.
Do. .	(282) Mr. K. C. Gupta	Do. . .	P. L. .	Not stated	10th November 1928.	1 year.
Do. .	(283) Mr. Amrit Lal P. Trivedi.	Do. . .	M. L. .	8	9th June 1928.	Do.
Do. .	(284) Messrs. Oke Brothers.	Do.	P. L.	50	10th September 1928.	Do.
Do. .	(285) Messrs. B. P. Byramji & Co.	Do.	M. L. (Supplementary).	13	30th August 1928.	Will expire with the original lease.
Do. .	(286) Mr. A. P. Trivedi	Do.	P. L.	24	20th July 1928.	1 year.
Do. .	(287) Mr. Diwanchand Jiwar.	Do. . .	P. L. .	72	22nd November 1928.	Do.
Do. .	(288) Mr. M. B. Marfatia.	Do. . .	P. L. .	39	29th May 1928.	Do.
Do . .	(289) Mt. Munna Bai.	Do. . .	P. L. .	59	12th December 1928.	Do.
Do. .	(290) Mr. Amrit Lal P. Trivedi.	Do. . .	P. L. .	53	14th September 1928.	Do.
Bhandara .	(291) Nawab Niazuddin Khan.	Do. . .	P. L. .	32	29th May 1928.	Do.
Do. .	(292) Messrs. S. Laxman Rao and B. Narsing Rao.	Do. . .	P. L. .	14	19th March 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara .	(293) Mr. B. V. Buti	Manganese . .	P. L. .	10	20th October 1928.	1 year.
Do. .	(294) Nawab Niazuddin Khan.	Do.	P. L.	40	27th March 1928.	Do.
Do. .	(295) Seth Ganeshlal Balbhadra.	Do. . .	P. L. .	128	8th June 1928.	Do.
Do. .	(296) Messrs. Nilkant Sao & Co.	Do. . .	P. L. .	58	3rd April 1928.	Do.
Do. .	(297) R. S. Seth Gowardhan Dass.	Do. . .	P. L. .	18	10th April 1928.	Do.
Do. .	(298) Nawab Niazuddin Khan.	Do. . .	P. L. .	30	27th March 1928.	Do.
Do. .	(299) Mr. K. C. Gupta	Do. . .	P. L. .	126	2nd August 1928.	Do.
Do. .	(300) Do. .	Do. . .	P. L. .	90	10th October 1928.	Do.
Do.	(301) Mr. M. A. Pasha, minor, through Guardian S. Alimuddin.	Do.	P. L.	19	14th June 1928.	Do.
Do.	(302) Messrs. Beharilal Atmaram Sao & Co	Do. .	P. L. .	39	12th August 1928.	Do.
Do. .	(303) Do. .	Do .	P. L. .	32	11th September 1928.	Do.
Do. .	(304) Messrs. Beharilal Atmaram Sao.	Do. . .	P. L. .	66	12th August 1928.	Do.
Do. .	(305) Mr. K. C. Gupta	Do. . . .	P. L. .	75	3rd November 1928.	Do.
Do. .	(306) Mr. Lalbehari and Ramcharan.	Do. . .	M. L. .	24	15th December 1928.	20 years.
Do. .	(307) Mr. Saminlla Khan.	Do. . .	M. L. .	66	1st February 1928.	30 years.
Do. .	(308) Messrs. Byramji & Co.	Do. . .	M. L. .	7	3rd March 1928.	5 years.
Do. .	(309) R. B. Bansilal Abirchand.	Do. .	M. L. .	53	28th May 1928.	Do.
Do. .	(310) Mr. M. A. Pasha, minor, through Guardian S. Alimuddin.	Do. .	M. L. .	4	7th July 1928	13 years.
Do .	(311) Mr. Shriram Seth	Do. . .	M. L. .	8	24th May 1928.	5 years.
Bilaspur .	(312) Messrs. Dunlop and Considine Ghordewa Coal Fields, Ltd.	Coal and Iron .	P. L. .	11,900	9th March 1928.	One year.
Chhindwara	(313) R. B. Nitya Gopal Bose, Nagpur.	Manganese . .	P. L. .	64	25th September 1928.	Do.
Do. .	(314) Mr. K. C. Gupta, Nagpur.	Do. . .	P. L. .	239	12th January 1928.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara	(315) Messrs. Misrilal Meghraj & Bros., Betul.	Maganese . .	P. L. .	268	19th April 1928.	One year.
Do. .	(316) Mr. Husain Khan, Chhindwara.	Coal . . .	P. L. .	198	30th March 1928.	Do.
Do. .	(317) S. Laxman Rao and B. Narsinghrao Naidu, Nagpur.	Manganese . .	P. L. .	41	16th January 1928.	Do.
Do. .	(318) Mr. Samiulla Khan, Dhotiwada.	Do. . .	P. L. .	13	18th February 1928.	Do.
Do. .	(319) Mr. A. V. Vazalwar, Nagpur.	Do. . .	P. L. .	118	8th May 1928	Do.
Do. .	(320) Do. .	Mica . . .	P. L. .	42	17th April 1928.	Do.
Do. .	(321) Do. .	Manganese . .	P. L. .	467	3rd April 1928.	Do.
Do. .	(322) Do. .	Do. . .	P. L. .	43	8th March 1928.	Do.
Do. .	(323) Nawab Niaz-uddin Khan.	Do. . .	P. L. .	150	17th May 1928.	Do.
Do. .	(324) Messrs. C. Harmasji and N. Rustamji, Nagpur.	Do. . .	P. L. .	120	10th March 1928.	Do.
Do. .	(325) Do. .	Do. . .	P. L. .	8	15th August 1928.	Do.
Do. .	(326) Mr. A.V. Vazalwar, Pleader, Nagpur.	Mica . . .	P. L. .	52	30th July 1928.	Do.
Do. .	(327) Mr. K. C Gupta, Nagpur.	Manganese . .	P. L. .	42	11th May 1928.	Do.
Do. .	(328) Mr. R. P. Mudliar, Proprietor, Independent Trading Co., Balaghat.	Do. . .	P. L. .	103	7th May 1928	Do.
Do. .	(329) Mr. Husain Khan, Chhindwara.	Do. . .	P. L. .	62	Do.	Do.
Do. .	(330) Do. .	Do. . .	P. L. .	32	24th August 1928.	Do.
Do. .	(331) Do. .	Do. . .	P. L. .	99	7th May 1928	Do.
Do. .	(332) Mr. A. V. Vazalwar, Pleader, Nagpur.	Do. . .	P. L. .	116	29th October 1928.	Do.
Do. .	(333) Lala Jagannath Prasad, Chhindwara.	Limestone .	P. L. .	29	27th August 1928.	Do.
Do. .	(334) Mr. A. V. Vazalwar, Pleader, Nagpur.	Manganese . .	P. L. .	139	29th October 1928.	Do.
Do. .	(335) Mr. Samiulla Khan, Dhotiwada, District Nagpur.	Do. . .	P. L. .	202	10th December 1928.	Do.

P. L.—Prospecting License. *M. L.—Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara	(336) Syed Haji Zahir-uddin of Parasia.	Coal . . .	M. L. .	250	18th June 1928.	30 years.
Do. .	(337) The P. V. Coal Co., Ltd., Parasia.	Do. . . .	M. L. .	46	20th April 1928.	14 years.
Do. .	(338) R. S. Minamal and Nandlal of Delhi.	Do. . . .	M. L. .	307	23rd March 1928.	30 years.
Drug . .	(339) Lal Indra Shah, Zamindar, Ambagarh Chowki.	Galena . .	P. L. .	12	22nd June 1928.	One year.
Jubbulpore	(340) Messrs. Ganpat Sao Dhanpat Sao.	Manganese . .	M. L. .	22	9th February 1928.	10 years.
Do. .	(341) Mr. G. H. Cook	Coal . . .	P. L. .	111	14th March 1928.	One year.
Do. .	(342) Mr A. V. Vazalwar.	Manganese . .	P. L. .	98	18th January 1928.	Do.
Do. .	(343) Mr. Kalyanji .	Yellow ochre .	P. L. .	26	18th April 1928.	Do.
Do. .	(344) Mr. Chhakorilal Pathak.	Bauxite . .	M. L. .	43	11th July 1928.	10 years.
Do. .	(345) Mr. G. Forrester	Oxide of iron and red ochre.	P. L. .	20	5th October 1928.	One year.
Do. .	(346) Mr. Kalyanji .	White clay .	P. L. .	17	30th July 1928.	Do.
Nagpur .	(347) Mr. Noor Muhammad Mitha.	Manganese . .	P. L. .	598	28th June 1928.	Do.
Do. .	(348) Mr. M. A. Razaq	Do. . .	P. L. .	77	17th April 1928.	Do.
Do. .	(349) Do. .	Do. . .	P. L. .	4	Do. .	Do.
Do. .	(350) Do. .	Do. . .	P. L. .	183	Do. .	Do.
Do. .	(351) Nawab Neazuddin Khan.	Do. . .	P. L. .	73	4th January 1928.	Do.
Do. .	(352) Mr. M A. Razaq	Do. . .	P. L. .	164	6th November 1928.	Do.
Do. .	(353) Nawab Neazuddin Khan.	Do. . .	P. L. .	35	18th January 1928.	Do.
Do. .	(354) Do. .	Do. . .	P. L. .	33	6th January 1928.	Do.
Do. .	(355) Messrs. Ganeshlal Balbhaddar.	Do. . .	P. L. .	107	20th January 1928.	Do.
Do. .	(356) Mr. A. C. Maitra	Do. . .	P. L. . .	58	12th January 1928.	Do.
Do. .	(357) Nawab Neazuddin Khan.	Do. . .	P. L. .	171	4th January 1928.	Do.
Do. .	(358) R. S. Gowardhandas.	Do. . .	P. L. .	20	12th January 1928.	Do.
Do. .	(359) Nawab Neazuddin Khan.	Do. . .	P. L. .	62	4th January 1928.	Do.

P. L. = *Prospecting Licence.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(360) Mr. Noor Mohmed Mitha.	Manganese . .	P. L. .	231	28th June 1928.	One year.
Do. .	(361) Mr. B. V. Buti .	Do. . .	P. L. .	96	1st February 1928.	Do.
Do. .	(362) Mr. K. C. Gupta	Do. . .	P. L. .	91	21st January 1928.	Do.
Do. .	(363) Mr. B. V. Buti .	Do. . .	P. L. .	47	17th August 1928.	Do.
Do. .	(364) Do.	Do. . .	P. L. .	50	18th May 1928	Do.
Do. .	(365) Do. .	Do. . .	P. L. .	82	9th March 1928.	Do.
Do. .	(366) Mr. A. V. Wazalwar.	Do. . .	P. L. .	468	8th March 1928.	Do.
Do. .	(367) Messrs. C. Hormasji and N. Rustumji.	Do. . .	P. L. .	91	15th February 1928.	Do.
Do. .	(368) Nawab Neazuddin Khan.	Do. . .	P. L. .	Not stated .	17th April 1928.	Do.
Do. .	(369) Messrs. Laxman Rao and B. Narsingh Rao.	Do. . .	P. L. .	30	23rd November 1928.	Do.
Do. .	(370) Mr. K. C. Gupta	Do. . .	P. L. .	82	4th May 1928	Do.
Do. .	(371) Messrs. B. Foujdar & Bros.	Do. . .	P. L. .	13	5th May 1928	Do.
Do. .	(372) Mr. B. V. Buti .	Do. . .	P. L. .	48	24th November 1928.	Do.
Do. .	(373) Mr. S. C. Das Gupta.	Do. . .	P. L. .	Not stated .	23rd September 1928.	Do.
Do. .	(374) Messrs. S. Laxman Rao and B. Narsing Rao.	Do. . .	P. L. .	30	23rd November 1928.	Do.
Do. .	(375) The Nagpur-Bhandara Manganese Co., Ltd.	Do. . .	P. L. .	58	14th August 1928.	Do.
Do. .	(376) Seth Partab Raghunath.	Do. .	P. L. .	190	1st December 1928.	Do.
Do. .	(377) Mr. B. V. Buti .	Do. . .	P. L. .	22	15th February 1928.	Do.
Do. .	(378) Mr. Noor Mohmad Mitha.	Do. . .	M. L. .	124	2nd July 1928	30 years.
Do. .	(379) Mr. M. A. Razaq	Do. . .	M. L. .	44	3rd October 1928.	Do.
Do .	(380) Mr. M. E. R. Malak.	Clay . . .	Q. L. .	4	5th April 1928	10 years.
Do. .	(381) Mr. Ganpat Sao Dhanpat Sao.	Manganese . .	M. L. .	26	22nd February 1928.	30 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(382) Mr. Bhawanji Naranji.	Manganese . .	M. L. .	14	8th March 1928.	30 years.
Do. .	(383) Mr. M. A. Razaq	Do. . .	M. L. .	19	5th February 1928.	Do.
Do. .	(384) Mr. Shamji Naranji.	Do. . .	M. L. .	2	17th February 1928.	10 years.
Do. .	(385) Messrs. C. Hormasji and N. Rustomji.	Do. . .	M. L. .	8	2nd March 1928.	5 years.
Do. .	(386) Mr. B. V. Bull .	Do. . .	M. L. .	26	14th March 1928.	30 years.
Do. .	(387) Mr. M. A Razaq	Do. . .	M. L. .	16	29th September 1928.	5 years.
Do. .	(388) Messrs. C. Hormasji and N. Rustomji.	Do . .	M. L. .	26	15th March 1928.	10 years.
Do. .	(389) Mr. Bhawanji Naranji.	Do. . .	M L. .	13	22nd August 1928.	15 years.
Do. .	(390) Maharaj Kumar Jugal Keshore Nath Shio Deo.	Do. . .	M. L. .	78	5th December 1928.	30 years.
Do. .	(391) Do. .	Do. . .	M. L. .	75	15th December 1928.	Do.
Do. .	(392) Mr. Shamji Naranji.	Do. . .	M. L. .	16	8th May 1928	15 years.
Do. .	(393) Mr. Ganpatrao Laxmanrao.	Do. . .	M. L. .	14	26th November 1928.	30 years.

MADRAS.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Anantapur .	(394) P. Venkayya .	Precious stones .	P. L. .	1,196·20	21st November 1927.	1 year.
Do. .	(395) K. Venkatasubbayya.	China clay . .	M. L. .	17·58	5th January 1928.	5 years.
Do. .	(396) Moka Pedda Narasayya.	Do. . .	M. L. .	14·54	20th September 1928.	Do.
Do. .	(397) M. Rajagopal Nayudu.	Mica . . .	P. L. .	30·75	13th December 1928.	1 year.
Do. .	(398) K. Venkata Subbayya.	Barytes . .	P. L. (renewal) .	22·25	1st September 1928.	Do.
Bellary .	(399) A. Pichayya Nayudu.	Manganese . .	M. L. .	367·56	4th May 1928	30 years.
Cuddapah .	(400) The Mysore Development Syndicate.	Asbestos . .	M. L. .	30·51	1st January 1928.	Do.
Do. .	(401) Do. .	Do. .	M. L. .	648·08	Do.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

MADRAS—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cuddapah .	(402) Mr. Sitaramachar.	Asbestos . .	P. L. .	104·59	4th September 1928.	1 year.
Do. .	(403) The East India Distilleries and Sugar Factories, Ltd.	China clay . .	M. L. .	10·00	13th June 1928.	20 years.
Do. .	(404) Mr. Henry A. Golwynne.	Absbestos . .	P. L. .	1,695·85	2nd June 1928.	1 year.
Do. .	(405) B. Seetharamachar.	Do. . .	P. L. .	184·53	4th September 1928.	Do
Do. .	(406) Mr. Henry A. Golwynne.	Do. . .	P. L. .	24·20	17th September 1928.	Do.
Do. .	(407) The Mysore Development Syndicate.	Do. . .	P. L. . (renewal).	538·93	26th July 1928.	6 months.
Do. .	(408) Do. .	Do. . .	P. L. . (renewal)	191·13	Do.	Do.
East Godavari.	(409) P. Venkayya .	Mica . . .	P. L. .	21·10	15th June 1928.	1 year.
Kurnool .	(410) H. M. D. Ashroof Hussain Khan Mendozie.	Barytes . .	P. L. .	12·00	27th January 1928.	Do.
Do. .	(411) B. P. Sesha Reddi	Do. . .	M. L. .	86·00	30th July 1928.	30 years.
Do. .	(412) Do. .	Lead ore . .	M. L. .	19·11	2nd June 1928.	Do.
Do. .	(413) H. M. D. Ashroof Hussain Khan, Mendozie.	Barytes . .	P. L. .	9·10	31st May 1928.	1 year.
Do. .	(414) V. Venkata Subbayya.	Do. . .	P. L. .	4·00	10th February 1928.	Do.
Do. .	(415) Do. .	Do. .	P. L. .	3·50	Do. .	Do.
Do. .	(416) H. M. D. Ashroof Hussain Khan, Mendozie.	Gold, copper, manganese.	P. L. .	78·00	17th March 1928.	Do.
Do. .	(417) Do. .	Manganese .	P. L. .	274·33	8th August 1928.	Do.
Do. .	(418) V. Venkata Subbayya.	Barytes .	P. L. .	9·22	28th July 1928.	Do.
Do. .	(419) B. P. Sesha Reddi	Do. . .	P. L. .	5·57	2nd December 1928.	Do.
Do. .	(420) Do. .	Do. . .	P. L. .	2·00	Do. .	Do.
Do. .	(421) S. P. Ranga Rao	Do. . .	P. L. .	2·30	15th November 1928.	Do.
Do. .	(422) V. Venkata Subbayya.	Do. . .	P. L. .	28·37	26th December 1928.	Do.
Do. .	(423) S. P. Ranga Rao	Do. . .	P. L. .	2·60	15th November 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

MADRAS—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore .	(424) G. Venkata-chalam Chetti.	Mica	M. L. .	0·80	3rd August 1928.	30 years.
Do. .	(425) M. Rama Rao .	Do.	P. L. .	11·19	29th October 1927.	1 year.
Do. .	(426) R. Gopal Reddi	Do.	M. L. .	34·12	21st April 1928.	30 years.
Do. .	(427) A. Pitchayya Nayudu.	Do. . . .	P. L. .	8·43	3rd August 1928.	1 year.
Do. .	(428) T. Venkata Subbayya Nayudu.	Do. . . .	M. L. .	6·16	6th December 1927.	30 years.
Do. .	(429) M. Dasaradha Rami Reddi.	Do.	P. L. .	303·62	21st December 1927.	1 year.
Do. .	(430) P. Gunniah Cotti	Do.	P. L. .	3·76	28th March 1928.	Do.
Do. .	(431) The Sankara Mining Syndicate.	Do. . . .	M. L. .	56·53	1st June 1928	22 years, 9 months.
Do. .	(432) T. Venkatasubbayya Nayudu.	Do.	M. L. .	36·86	2nd February 1928.	30 years.
Do. .	(433) T. Rami Reddi	Do. . . .	M. L. .	4·43	6th December 1927	Do.
Do. .	(434) G. Chench Subba Reddi.	Do. . . .	P. L. .	12·61	30th September 1927.	1 year.
Do. .	(435) A. Narasimham	Do. . . .	P. L. .	7·34	16th April 1928.	Do.
Do. .	(436) P. Venkata-subba Reddi.	Do. . . .	M. L. .	1·54	1st June 1928	30 years.
Do. .	(437) R. Ramalingam Chetti.	Do. . . .	M. L. .	23·90	17th February 1928.	Do.
Do. .	(438) T. Seshadri Redd .	Do. . . .	P. L. .	15·22	13th July 1928.	1 year.
Do. .	(439) G. V. Subba Reddi.	Do. . . .	P. L. .	4·47	23rd November 1927.	Do.
Do. .	(440) B. Subbamma .	Do. . . .	M. L. .	3·40	1st December 1928.	30 years.
Do. .	(441) I. Ramasubba Reddi.	Do.	M. L. .	14·78	22nd June 1928.	Do.
Do. .	(442) T. Vasu . .	Do. . . .	P. L. .	8·35	13th October 1927.	1 year.
Do. .	(443) Do. .	Do.	P. L. .	28·87	22nd December 1927.	Do.
Do. .	(444) P. Papi Reddi .	Do.	P. L. .	21·18	6th December 1927.	Do.
Do. .	(445) P. Venkata-subba Reddi.	Do.	M. L. .	85·35	22nd December 1927.	30 year.
Do. .	(446) M. Rama Rao .	Do.	P. L. .	6·05	6th February 1928.	1 year.

P. L. = *Prospecting License.* *M. L. = Mining Lease.*

MADRAS—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore .	(447) R. Harishchendra Reddi.	Mica . . .	P. L. .	42·95	3rd August 1928.	1 year.
Do. .	(448) Do. .	Do. . .	P. L. .	35·39	Do. .	Do.
Do. .	(449) B. Subbamma .	Do. . .	M. L. .	439·87	28th September 1928.	Up to 8th February 1956
Do. .	(450) T. Ramu Reddi	Do. . . .	M. L. .	3·72	6th December 1927.	30 years.
Do. .	(451) P. K. Venkanna Nayudu.	Do. . . .	M. L. .	63·67	1st January 1928.	Up to 10th October 1948.
Do. .	(452) The Tallabodu Co., Ltd.	Do. . .	M. L. .	4·78	17th January 1928.	30 years.
Do. .	(453) P. Venkatanarasimhulu Chetti.	Do. . .	M. L. .	62·37	7th December 1927.	Up to 23rd September 1956.
Do .	(454) P. Veera Reddi	Do. . . .	P. L. .	4·42	10th June 1928.	1 year.
Do. .	(455) T. Rama Reddi and M. Dasaradha Rami Reddi.	Do. . . .	M. L. .	0·56	11th January 1928.	Up to 31st December 1936.
Do. .	(456) G. Chenchusubba Reddi.	Do. . . .	P. L. .	40 74	15th April 1928.	1 year.
Do. .	(457) T. C. Dandayutham Pillai.	Do. . . .	M. L. .	49·66	16th April 1928.	30 years.
Do. .	(458) R. Ramalingam Chetti.	Do. . . .	M. L. .	35·40	26th July 1928.	Do.
Do. .	(459) A. Rama Nayudu.	Do. . . .	P. L. .	69·19	15th June 1928.	1 year.
Do. .	(460) Do. .	Do. . . .	P. L. .	41·19	Do.	Do.
Do. .	(461) The General Corporation, Ltd.	Do. . . .	P. L. .	7·92	16th April 1928.	Do.
Do. .	(462) Do. .	Do. . . .	P. L. .	6·30	Do. .	Do.
Do. .	(463) P. Veera Reddi	Do. . . .	M. L. .	21·03	10th June 1928.	30 years.
Do. .	(464) Do. .	Do. . . .	M. L. .	77·58	12th July 1928.	Do.
Do. .	(465) A. Rama Nayudu	Do. . . .	P. L. .	111·85	25th March 1928.	1 year.
Do .	(466) V. Venkata Subbayya.	Do. . . .	P. L. .	85·61	28th September 1928.	Do.
Do. .	(467) C. Venkatarami Chetti.	Do. . . .	M. L. .	19·53	17th December 1928.	30 years.
Do. .	(468) K. Kodandarami Reddi.	Do. . . .	P. L. .	1·08	13th November 1928.	1 year.
Do. .	(469) C. Ramayya Chetti.	Do. . . .	P. L. .	27·75	26th July 1928.	Do.
Do. .	(470) K. Kodandarami Reddi.	Do. . . .	P. L. .	12·86	17th August 1928.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

MADRAS—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore .	(471) K. Kodandorami Reddi.	Mica . . .	P. L. .	23·56	13th November 1928.	1 year.
Do. .	(472) B. Veeraraghavayya Chetti.	Do. . . .	M. L. .	67·40	13th July 1928.	Up to 8th September 1956.
Do. .	(473) A. Sankarayya .	Do. . . .	P. L. .	5·80	17th August 1928.	1 year.
Do. .	(474) A. Rama Nayudu	Do. . . .	P. L. .	7·04	28th September 1928.	Do.
Do. .	(475) I. Ramasubba Reddi.	Do. . . .	M. L. .	6·48	27th June 1928.	30 years.
Do. .	(476) P. Venkayya .	Do. . . .	P. L. .	82·23	19th October 1928.	1 year.
Do.	(477) K. Kodandarami Reddi.	Do. . . .	P. L. .	19·76	13th November 1928.	Do.
Do. .	(478) Do. .	Do. . . .	P. L. .	29·56	19th October 1928.	Do.
Do. .	(479) Y. Audemma .	Do. . . .	M. L. .	1·31	4th December 1928.	30 years.
North Arcot	(480) Mr. Henry A. Golwynne.	Pyrites . .	P. L. .	1,280·00	2nd March 1928.	1 year.
Do. .	(481) Do. .	Do . . .	P. L. .	424·00	25th May 1928.	Do.
Salem .	(482) Mon. E Gandart of Pondicherry.	Magnesite and chromite.	M. L .	61 68	12th March 1928.	30 years.
Do. .	(483) Do. .	Magnesite . .	M. L. .	1,128 42	Do. .	24 years 6 months and 2 days.

NORTH-WEST FRONTIER PROVINCE.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bannu .	(484) The Indo-Burma Petroleum Co., Ltd.	Natural Petroleum including natural gas.	P. L. . (renewal)	10,880	3rd February 1928.	1 year.
Do. .	(485) Do. .	Do. . .	P. L. . (renewal)	3,040	4th August 1928.	Do.
Do. .	(486) The Burmah Oil Co., Ltd.	Do. .	P. L. . (renewal)	21,446·4	Do	Do.
Do. .	(487) Do. .	Do. .	P. L. . (renewal)	1,088	18th July 1928	Do.
Do. .	(488) Do. .	Do. .	P. L. . (renewal)	512	29th September 1928.	Do.
Do. .	(489) Do. .	Do. .	P. L. . (renewal)	1,632	Do .	Do.
Dera Ismail Khan.	(490) Do. .	Do. .	P. L. .	2,802·8	8th June 1928.	Do.
Do. .	(491) The Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. . (renewal)	6,720	10th March 1928.	Do.
Do. .	(492) Do. .	Do. .	P. L. . (renewal)	2,995·2	10th September 1928.	Do.
Do. .	(493) The Burmah Oil Co., Ltd.	Do. .	P. L. . (renewal)	4,640	10th May 1928.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

PUNJAB.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jhelum .	(494) Pt. Gian Chand, Colliery Proprietor, Dandot	Coal . . .	P. L. .	50·5	22nd September 1928.	1 year.
Do. .	(495) L. Ishar Das Kapur, Colliery Proprietor, P. D. Khan.	Do. . . .	M. L. . (renewal)	151	24th January 1928.	15 years.
Do. .	(496) Subedar Hakim Khan of Wahula.	Do. . . .	M. L. .	57·5	1st May 1927	5 years.
Rawalpindi	(497) S. B. Malik Mohan Singh, Rawalpindi.	Natural petroleum	P. L. .	89	2 1st July 1928.	2 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

SUMMARY.

PROVINCE.	Exploring License.	Prospecting License.	Mining Lease.	Total of each Province.
Ajmer-Merwara	..	23	3	26
Assam	..	14	2	16
Baluchistan	..	1	1	2
Bengal	..	2	..	2
Bihar and Orissa	..	7	1	8
Bombay	..	10	1	11
Burma	..	169	14	183
Central Provinces	..	103	42 (*a*)	145
Madras	..	55	35	90
N.-W. F. Province	..	10	..	10
Punjab	..	2	2	4
Total of each kind and grand total, 1928 .	..	396	101	497
TOTAL FOR 1927	2	603	109	714

(*a*) Includes one Quarry Lease.

Classification of Licenses and Leases.

TABLE 43.—*Prospecting Licenses and Mining Leases granted in Ajmer-Merwara during the year 1928.*

DISTRICT.	1928. No.	1928. Area in acres.	1928. Mineral.
PROSPECTING LICENSES.			
Ajmer	12	30·2	Mica.
Do.	1	2·00	Mica, beryl and acquamarine.
Beawar	10	29·7	Mica.
TOTAL	23	..	
MINING LEASES.			
Ajmer	2	20·00	Mica.
Beawar	1	7·01	Mica.
TOTA	3	..	

TABLE 44.—*Prospecting Licenses and Mining Leases granted in Assam during the year 1928.*

DISTRICT.	1928. No.	1928. Area in acres.	1928. Mineral.
PROSPECTING LICENSES.			
Cachar	2	1,748·8	Mineral oil.
Khasi and Jaintia Hills	1	2,880·0	Coal.
Lakhimpur	6	2,53,632·0	Mineral oil
Do.	1	3,616·0	Coal.
Sadiya Frontier Tract	1	2,240·0	Mineral oil.
Sibsagar	1	614,400·0	Do.
Sylhet	2	12,600·28	Do.
TOTAL	14	..	
MINING LEASES.			
Khasi and Jaintia Hills	1	1,920·0	Sillimanite, Corundum, etc.
Lakhimpur	1	2,624·0	Mineral oil.
TOTAL	2	..	

TABLE 45.—*Prospecting License and Mining Lease granted in Baluchistan during the year 1928.*

DISTRICT.	1928.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSE.		
Kalat	1	3,200	Mineral oil.
	MINING LEASE.		
Kalat	1	80	Coal and coal dust.

TABLE 46.—*Prospecting Licenses granted in Bengal during the year 1928.*

DISTRICT.	1928.		
	No.	Area in acres.	Mineral.
Chittagong	1	4,000·0	Natural Petroleum.
Chittagong Hill Tracts . .	1	4,313·6	Mineral oil.
TOTAL .	2	..	

TABLE 47.—*Prospecting Licenses and Mining Lease granted in Bihar and Orissa during the year 1928.*

DISTRICT.	1928.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Singhbhum	1	1,491·20	Chromite.
Do.	2	3,466·20	Iron ore and manganese.
Do.	2	1,590·40	Manganese.
Do.	1	36·60	Manganese and yellow ochre.
Do.	1	379·25	Manganese and red ochre.
TOTAL .	7	..	
	MINING LEASE.		
Santal Parganas . . .	1	1	Coal.

TABLE 48.—*Prospecting Licenses and Mining Lease granted in the Bombay Presidency during the year 1928.*

DISTRICT.	1928. No.	1928. Area in acres.	1928. Mineral.
	PROSPECTING LICENSES.		
Belgaum	1	60	Bauxite.
Do.	5	786	Manganese.
Kanara	4	2,163	Do.
TOTAL	10	..	
	MINING LEASE		
Belgaum	1	320	Manganese.

TABLE 49.—*Prospecting Licenses and Mining Leases granted in Burma during the year 1928.*

DISTRICT.	1928. No.	1928. Area in acres.	1928. Mineral.
	PROSPECTING LICENSES.		
Akyab	3	5,660·8	Natural petroleum (including natural gas).
Amherst	6	6,022·4	All minerals except oil.
Henzada	1	3,200·0	Mineral oil.
Lower Chindwin	4	1,531·2	Natural petroleum (including natural gas).
Magwe	5	18,880·0	Petroleum.
Do.	3	1,990·4	Natural petroleum (including natural gas).
Mergui	9	5,762·5	Tin and allied minerals.
Do	28	15,487·0	Tin.
Do.	10	7,008·0	All minerals except oil.
Do.	18	11,640·4	Tin and allied minerals except oil.
Do.	4	1,094·4	Tin and other allied metals.
Do.	1	620·8	Tin and wolfram.
Do.	2	6,105·6	All minerals other than petroleum and precious stones.
Do.	1	512·0	Tin and Gold.
Minbu	1	288·0	Natural petroleum.
Myingyan	1	1,280·0	Mineral oil.
Northern Shan States	3	545·9	Iron ore.
Do. do.	2	2,291·8	Lead and Silver.
Pakokku	5	5,856·0	Natural petroleum.

TABLE 49.—*Prospecting Licenses and Mining Leases granted in Burma during the year 1928*—contd.

District.	1928. No.	1928. Area in acres.	1928. Mineral.
	PROSPECTING LICENSES—*contd.*		
Salween	1	2,560·0	All minerals except mineral oil.
Shwebo	1	5,113·6	Natural petroleum.
Southern Shan States	5	15,584·0	All except oil.
Tavoy	1	1·9	Tin.
Do.	43	27,268·0	Tin and wolfram.
Thayetmyo	5	19,762·4	Mineral oil.
Upper Chindwin	6	18,313·6	Natural petroleum.
TOTAL	169	..	
	MINING LEASES.		
Mergui	6	4,390·4	Tin and allied minerals.
Do.	1	428·8	All minerals except precious stones and mineral oil.
Do.	3	2,278·4	Tin.
Do.	1	441·6	Wolfram, tin and other minerals.
Do	1	25·6	Tin ore and allied minerals except mineral oil.
Southern Shan States	1	89·6	All except oil.
Tavoy	1	601·6	Tin and wolfram.
TOTAL	14	..	

TABLE 50.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during the year 1928.*

District.	1928. No.	1928. Area in acres.	1928. Mineral.
	PROSPECTING LICENSES.		
Balaghat	27	2,468	Manganese.
Bhandara	15	786	Do.
Bilaspur	1	11,900	Coal and Iron.
Chhindwara	19	1,926	Manganese.
Do.	1	198	Coal.
Do.	2	94	Mica.
Do.	1	29	Limestone.
Drug	1	12	Galena.

TABLE 50.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during the year 1928*—contd.

District.	1928.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES—*contd*		
Jubbulpore	1	98	Manganese.
Do.	1	111	Coal.
Do.	1	26	Yellow ochre.
Do.	1	20	Oxide of iron and red ochre.
Do.	1	17	White clay.
Nagpur	31	3,214	Manganese.
TOTAL .	103	..	
	MINING LEASES.		
Balaghat	15	675	Manganese.
Bhandara	6	162	Do.
Chhindwara	3	603	Coal.
Jubbulpore	1	22	Manganese.
Do.	1	43	Bauxite.
Nagpur	15	501	Manganese.
TOTAL .	41	..	
	QUARRY LEASE.		
Nagpur	1	4	Clay.

TABLE 51.—*Prospecting Licenses and Mining Leases granted in Madras during the year 1928.*

District.	1928.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Anantapur	1	1,196·2	Precious stones.
Do.	1	30·75	Mica.
Do.	1	22·25	Barytes.
Cuddapah	6	2,739·23	Asbestos.
East Godavari	1	21·10	Mica.
Kurnool	10	78·66	Barytes.
Do.	1	78·00	Gold, copper, manganese.
Do.	1	274·33	Manganese.
Nellore	31	1,084·27	Mica.
North Arcot . .	2	1,704·00	Pyrites.
TOTAL .	55	..	

TABLE 51.—*Prospecting Licenses and Mining Leases granted in Madras during the year 1928*—contd.

District	1928. No.	1928. Area in acres	1928. Mineral.
	MINING LEASES.		
Anantapur	2	32·12	China clay.
Bellary	1	367·56	Manganese.
Cuddapah	2	678·59	Asbestos.
Do.	1	10·00	China clay.
Kurnool	1	86·00	Barytes.
Do.	1	19·11	Lead ore.
Nellore	25	1,071·18	Mica.
Salem	1	61·68	Magnesite and chromite
Do.	1	1,128·42	Magnesite.
TOTAL	35	..	

TABLE 52.—*Prospecting Licenses granted in the N.-W. F. Province during the year 1928.*

District.	1928. No.	1928. Area in acres.	1928. Mineral.
	PROSPECTING LICENSES.		
Bannu	6	38,598·4	Natural petroleum including natural gas.
Dera Ismail Khan	4	17,248·0	Do.
TOTAL	10	..	

TABLE 53.—*Prospecting Licenses and Mining Leases granted in the Punjab during the year 1928.*

District.	1928. No.	1928. Area in acres.	1928. Mineral.
	PROSPECTING LICENSES.		
Jhelum	1	50·5	Coal.
Rawalpindi	1	89·0	Natural petroleum.
TOTAL	2	..	
	MINING LEASES.		
Jhelum	2	208·5	Coal.

GRANOPHYRIC TRACHYTE FROM SALSETTE ISLAND, BOMBAY.

BY M. S. KRISHNAN, M.A., PH.D. (LOND.), A.R.C.S., D.I.C., *Assistant Superintendent, Geological Survey of India.*

Occurrence.

THE specimen described here (Regd. No. 36/35) was collected by Dr. C. S. Fox of the Geological Survey of India, from one of the quarries at Kharodi, near Malovni, about four miles west of Malad station (19° 12′; 72° 51′), in the island of Salsette. This quarry provided the stone for the Gateway of India, Bombay, and it was the pyritic decomposition and the resulting iron stains on the exposed surface of this Gateway that aroused Dr. Fox's curiosity as to the real nature of the rock. He remarks that there is no reason to doubt Mr. Hallowes' diagnosis that the rock forms part of a lava flow. The quarry exposure, however, is not clear owing to the debris from the dressing and breaking operations. Dr. Fox calls attention to the resemblance between the so-called Kurla trap in the north-east part of Bombay Island and the Karodi material, although the former is evidently more weathered and is buff in colour. Salsette Island is composed of lava flows belonging to the Deccan Trap formation. Some of these flows are of a sub-acid composition, and are presumably differentiates of the original basaltic magma. The present specimen is fairly representative of the middle portion of one of these sub-acid flows.

Similar acidic rocks in Deccan Trap.

Other occurrences of sub-acid and acid rocks, either as constituent flows differentiated from the original magma, or as intrusive masses in the trap, are known in Kathiawar and western Bombay. At Pawagarh near Baroda, Dr. L. L. Fermor [1] found rhyolites, pitchstones, dacites and quartz-andesites. Dr. C. S. Fox [2] has noted the occurrence of acid lavas at Sewri Fort and the Worli hill in Bombay Island. Rhyolites from the Osham hill, and syenites, nepheline-syenites, diorites (as well as more basic rocks) from the Girnar hills, have been described by the writer,[3] the field-relation-

[1] "Lavas of Pavagad Hill." *Rec., Geol. Surv. Ind.*, XXXIV, p. 148 (1906).
[2] "Bitumen in Bombay Island." *Rec., Geol. Surv. Ind.*, LIV, p. 117 (1922).
[3] "Petrography of rocks from Girnar and Osham hills." *Rec., Geol. Surv. Ind.*, LVIII, p. 380 (1925-26).

ships of the Girnar rocks forming the subject of a paper by Mr. K. K. Mathur and others.[1]

The specimen is light cream coloured, fine-grained and contains very few dark minerals. A few specks of metallic yellow pyrite, as well as yellow-brown limonitic matter, can be discerned on close observation. Pronounced phenocrysts are absent, but there are a few crystals of quartz and felspar, which are somewhat larger in size than the minerals in the groundmass.

Megascopic characters.

Mr. K. A. K. Hallowes, who worked in this area some years ago, conducted some physical tests on rocks from the same quarries. According to him,[2] the density of the material was 144·4 lbs. per cubic foot (*i.e.*, Spec. Grav. 2·31), porosity 3·14 per cent of the volume, and the crushing strength 1,531 tons per square foot. The stone splits evenly and regularly, and is easily dressed for building purposes.

Physical characters.

The specific gravity of the specimen, as tested in the Geological Survey laboratory, is 2·431.

Under the microscope, a thin section of the rock (Regd. No. 19,182) is seen to be fairly fine-grained, holocrystalline and highly felspathic. A suggestion of flow, as well as of granophyric structure, can be seen in some parts of the section. The major part of the felspar is untwinned and presumably of the composition of orthoclase (partly soda-orthoclase ?), the refractive index being lower than that of Canada balsam. Some of the crystals are rectangular or square in section (sanidine), a few giving straight extinction with reference to the crystal outlines. Some oligoclase is also present, a few of the crystals showing lamellar twinning. In general, the felspars show incipient sericitization.

Microscopic characters.

A fair amount of calcite is present in the rock, the application of dilute hydrochloric acid producing an effervescence on a hand-specimen. Many of the crystals are tinged slightly yellowish in the section; this may be due to the presence in them of the ankerite molecule. The calcite is probably all secondary.

There are a few crystals of quartz, and numerous very slender needles of apatite present.

[1] *Journal of Geology* (U. S. A.) Vol. XXXIV, 1926), p. 280.

[2] "Geology and Mineral Resources of Salsette." Poona (1922), p. 20, No.Q.-59.

No distinct ferromagnesian minerals have been noticed although some of the dirty brown patches may represent original pyroxene or amphibole. A number of grains of pyrite are present, some being partly decomposed to limonitic matter.

As already remarked, a few of the crystals of quartz and felspar tend to impart a porphyritic structure to the rock, though they are only slightly larger than the minerals of the groundmass.

Chemical composition.

In the following table, an analysis of the rock, made by the writer is given in column (A). For comparison are added the compositions of: (B) a typical syenite, (C) the world average of trachytic rocks, and (D) a rock from Salsette apparently similar to the one under description.

	A	B.	C.	D.
SiO_2	61·54	61·65	60·68	72·2
TiO_2	Trace.	0·56	0·38	..
Al_2O_3	15·82	15·07	17·74	17·4
Fe_2O_3	0·26	2·03	2·64	7·1
FeO	3·79	2·25	2·62	..
MnO	not determined	0·09	0·06	..
MgO	Trace.	3·67	1·12	..
CaO	3·36	4·61	3·09	1·6
Na_2O	6·21	4·35	4·43	..
K_2O	4·61	4·50	5·74	..
$H_2O(-)$	0·24	0·26	1·26	2·0 (ignition)
$H_2O(+)$	1·59	0·41		
CO_2	0·96	..	..	..
P_2O_5	0·71	0·33	0·24	..
FeS_2	1·70	..	..	..
BaO	..	0·27	..	..
SrO	..	0·10	..	..
TOTAL	100·79	100·15	100·00	100·3

A. Rock under description. Analysed by M. S. Krishnan.

B. Syenite, Yogo Peak, Montana (U. S. A.). Analysed by Hillebrand. Contains orthoclase, oligoclase, quartz, apatite, titanite, iron ores, pyroxene, hornblende, with traces of decomposition products. (From F. W. Clarke, "Data of Geochemistry," (1920), p. 435. Analysis I).

C. Average composition of trachytes (48 analyses). From R. A. Daly, "Igneous rocks and their origin." (1914), p. 21, column 18.

D. Rock said to be similar to A. Analysed by A. J. Turner of Bombay. From Hallowes, *op. cit.*, p. 2.

Norm minerals calculated from A.

	per cent.
Quartz	2·94
Orthoclase	27·24
Albite	52·40
Anorthite	2·50
Diopside ($FeO.SiO_2$)	6·73
Do. ($CaO.SiO_2$)	1·62
Pyrite	1·70
Calcite	2·20
Apatite	1·55
Magnetite	0·46
Water	1·83
TOTAL	101·17

Nomenclature.

Mr. Hallowes has described the Kharodi rock and other similar rocks from Salsette as "pale greyish white, altered, porphyritic basalt." Some of his own specimens and thin sections were examined, but they do not bear out this description. In the present case, the examination of the thin section and the chemical analysis makes it clear that the rock belongs to the syenite family. The fine-grained texture, the crystallisation in two distinct generations, the presence of felspar of sanidine habit, and a certain degree of flow recalling trachytic structure, all go to show that the rock is most closely allied to the trachytes. The absence of a glassy residue in the groundmass, so general in trachytes, also favours the above view. Since, in addition to the above characters, the texture is also somewhat granophyric, the rock may be called, following a suggestion by Dr. Fermor, '*granophyric trachyte.*'

Norm and mode.

A comparison between the norm and the mode shows a fair agreement. Quartz seems to be more in evidence in the mode than in the norm, probably because of the fact that some of the silica shown as forming diopside is really free, as there is an appreciable amount of limonitic matter in the free state. Moreover, the diopside of the norm is found in the form of decomposed ferromagnesian mineral in the mode. The norm value of the apatite also seems to be in excess of

the mode, but this may be due to the minute needle-like form in which it occurs.

Other Indian trachytes.

The record of occurrences of trachyte in India is meagre. Blanford[1] has observed an intrusive trachytic rock at the margin of the Nummulitic series near Padwani, in the Narbada valley. Ball[2] has recorded trachytic porphyry in a group of small conical hills called Gandesuri, close to the Simra bungalow in the Rajmahals, the rock being described as "a pinkish trachyte, which is prophyritic in places, in others vesicular." But, on examining thin sections of the above rock, McMahon[3] came to the conclusion that it was really an andesite. Mr. H. C. Das-Gupta[4] has recently recorded the occurrence of a "white trap" from Dharavee, Bombay, which is said to be remarkably similar to the rock described here.

Defects as a building stone.

It will be of interest to note that the rock under description is a popular building stone in Bombay. The famous "Gateway of India" has been constructed of this stone. Fresh from the quarries, it has a pleasing colour and desirable physical characters, but mineralogically, it contains appreciable amounts of harmful minerals. With exposure to the weather, the pyrite in the rock gives rise to sulphuric acid and ferric hydrate and the latter, probably in a colloidal form, spreads over the stones, producing patches of yellows and browns. The sulphuric acid, at the same time, attacks the calcite in the rock, and forms gypsum. The replacement of calcite by gypsum is attended by expansion in volume, and there is also a constant tendency on the part of the gypsum to grow along cracks in the rock.

The question of the importance of gypsum as an effective agent in rock decay is dealt with by Dr. A. P. Laurie[5] who states that the decay is due, not so much to the expansion in volume during replacement, but to the persistent growth of gypsum along certain lines.

[1] *Mem., Geol. Surv. Ind.*, VI, Pt. 3, p. 59, (1869).

[2] *Mem., Geol. Surv. Ind.*, XIII, Pt. 2, p 66 (1877).

[3] *Rec Geol. Surv. Ind.*, XX, p. 107 (1887).

[4] "Notes on the geology of Bombay Island." Calcutta Univ. *Journ. Dept. Sci.*, VIII, p. 127 (1927).

[5] "Stone Decay and Preservation of Buildings." *Journ. Soc. Chem. Industry*, Vol. 44. No. 9, pp. 86T-92T (Feb. 1925).

In the "Gateway of India," the discoloration due to the spread of ferric hydrate is easily noticeable, but the formation of gypsum does not seem to have proceeded far enough to cause any concern.

In view of the above defects, the rock should be selected with care at the quarries so as to have the minimum of the harmful minerals, particularly if it is to be utilized in the construction of monuments.

THE COAL RESOURCES OF THE JHARIA COALFIELD. BY NORMAN BARRACLOUGH, B.SC., *Inspector of Mines in India.*

IN a report published in 1867 Dr. Oldham, Director, Geological Survey of India, estimated that there were 465 million tons of coal in the Jharia coalfield. In 1913 Sir Henry Hayden ("The Coal Resources of the World"; published under the authority of the International Geological Congress) estimated that there were 500 million metric tons of coal of first class quality in the field. In 1913 Mr. R. R. Simpson (*Memoirs Geol. Surv. Ind.*, XLI, page 52) calculated that within a depth of 500 feet of the surface there were 420 million tons of coal of first class quality in the area. In 1920 Mr. R. R. Simpson (*Transactions, Mining and Geological Institute of India*, Volume XV, page 26) estimated that, within a depth of 1,500 feet and deducting one-third for coal already worked or unworkable, there were 1,174 millions tons of coking coal in the Jharia coalfield. Subsequent estimates have been based on these figures, and various estimates were given in the voluminous discussion on Dr. C. S. Fox's paper "The raw materials for the iron and steel industry for India" (*Transactions, Mining and Geological Institute of India*, Volume XX, pp. 331–422).

In 1917 Mr. R. G. M. Bathgate in a presidential address to the members of the Mining and Geological Institute of India (*Transactions*, Volume XII, p. 13) drew attention to the losses entailed by wasteful methods of mining coal in India, and stated that with coal seams of great thickness the loss may be anything between 50 and 75 per cent. Three years later the Coalfields Committee was appointed by the Government of India to report the action which it is possible and expedient to take to prevent waste of coal in the Raniganj and Jharia coalfields. In its published report (1920) the Committee's chief recommendation was that there should be a controlling authority with legal powers designed to ensure conservation and economic extraction. The more the subject was examined, however, the greater did the difficulties appear to be, and no steps have as yet been taken to carry out this recommendation.

For those who are not well acquainted with the Jharia coalfield a brief history and description of the field, will not be out of place at this stage.

By the extension of the East Indian Railway Company's Barakar branch this coalfield first obtained railway connection in 1894, in which year 1,500 tons of coal were produced. In the following year a branch from Kusunda to Pathardih was opened. In 1899, the Bengal Nagpur Railway Company sanctioned an extension of their line from Midnapur to Bhojudih, and in 1903 they extended their lines into the coalfield.

In 1899 the annual production was over a million tons; in 1905 the three million ton mark was passed and in 1906 the production outstripped that of the neighbouring Raniganj field, and the Jharia field assumed the lead and became the largest producer of coal in the Indian Empire.

The coalfield is roughly elliptical in shape and contains about 150 square miles of coal-bearing rocks of the Damuda series. In the Raniganj beds, which are exposed over about 30 square miles in the south-western portion of the field, several thin seams of coal occur, some of which are of very good quality. As they do not contain any good coking coal they have been excluded from the ensuing remarks and figures. The thickest and most valuable seams of coal occur among the Barakar beds which are exposed over the remaining part of the area. For purposes of recognition these seams have been numbered from the bottom upwards. The seams 12 to 18 which are at the top of the series constitute the most valuable reserves in India of good coking coal suitable for metallurgical purposes. Although the coal from some of the lower seams exhibits strong coking properties it is unsuitable for making blast furnace coke because of its high ash content. The reserves of low grade coal in the lower seams are enormous but the reserves of high grade coking coal are limited.

In 1926 an enquiry into the quantity of coal lost in India by fires and collapses was ordered by the Government of India and during that enquiry valuable information about the reserves of coking coal in the Jharia coalfield was obtained. Mine-owners, agents and managers kindly furnished data obtained by measurements taken direct from their mine plans; the data for each seam were given separately. To ensure accuracy many mines were visited and the data checked. After the necessary calculations had been

made the figures were tabulated and summarised. The results have been brought up to date to the end of 1927 and are given in the table appended.

As the seams go down to great depths in some parts of the field, it has been necessary in making the estimation to work to a definite depth. A depth of 1,000 feet was chosen during this investigation, and no coal below this depth has been included in the figures in the table. It should not be assumed that this depth is given as the limit to which coal can be extracted at a profit, as there is no doubt that as the shallow coal in the best seams approaches exhaustion, it will be possible, with the aid of modern machinery and up-to-date methods of mining, economically to extract coal from depths of 2,000 feet and probably from even greater depths.

An allowance of 20 per cent. has been made for dykes, faults, barriers, unknown burnt areas, bands of stone in the seam, etc., and all coal which is known to have been burnt by igneous intrusions has been excluded. The total quantity of coal which has been lost by fires and collapses is estimated to be 15,612,832 tons up to the end of 1927. The difference of columns 1 and 3 in the table—187 million tons approximately- is the quantity of coal exploited. After a careful scrutiny of the output records of each colliery the total output of coal obtained from the seams given in the table has been found to be approximately 143 million tons.

The percentage loss of coal exploited may be deduced as follows :—

	Million tons.
(*a*) Quantity of coal exploited	187.
(*b*) Output of coal obtained	143.
(*c*) Difference (*a*—*b*)	44.
(*d*) Percentage loss of coal exploited $\frac{44 \times 100}{187}$ = 23·53 per cent.	

The loss of 23·53 per cent. of the coal exploited does not, however, represent the true state of affairs, for in many areas only the first working has been conducted and in obtaining an output o. 143 million tons pillars containing 131 million tons have been left standing.

In the formation of pillars the percentage loss is much smaller than in pillar extraction and losses are confined to the following :—

1. Premature collapses.
2. Fires resulting from premature collapses.
3. Coal lost by theft.
4. Free supply of coal to miners which is not included in the output.

If it be assumed that 40 per cent. of coal is extracted in the formation of pillars, then in forming pillars containing 131 million tons, $\frac{131 \times 40}{60} = 87 \cdot 3$ million tons were extracted. The quantity of coal lost by fires and collapses in areas where pillar extraction had not been commenced has been found to be approximately 9 million tons. If we make the reasonable assumption that, on an output basis, 3 per cent. of coal is lost by theft and free supply to miners, then of the 87 million tons extracted in the formation of pillars, approximately 3 million tons were lost and 84 million tons were obtained as output. In forming the pillars which contain 131 million tons of coal $9+3+84=96$ million tons were exploited and $9+3$ million tons were lost. The percentage loss of coal exploited during the formation of these pillars was, therefore, $\frac{12 \times 100}{96} =$ *12·5 per cent.*

The percentage of coal *in situ* lost during the formation of pillars may be estimated in the following manner:--

	Million tons.
(*e*) Quantity of coal now standing in pillars . . .	131
(*f*) Quantity of coal in pillars lost by fires and collapses .	9
(*g*) Total	140
(*h*) Assuming 60 per cent. of coal is left in pillars then the quantity of coal *in situ*	233
(*i*) Percentage of coal *in situ* lost during the formation of pillars$=\frac{12 \times 100}{233}=$*5·15 per cent.*	

The quantity of coal which has been obtained by complete extraction is the difference between 143 and 84 million tons, *i.e.*, 59 million tons.

The percentage loss of coal *in situ* during complete extraction may be deduced as follows:—

	Million tons.
(*j*) Total quantity of coal exploited	187
(*k*) Quantity exploited in the formation of existing pillars.	96
(*l*) Quantity exploited in worked-out areas	91
(*m*) Total coal lost (*c*)	44
(*n*) Coal lost in forming existing pillars	12
(*p*) Coal lost in worked-out areas	32
(*q*) Percentage of coal *in situ* lost in worked-out areas$=\frac{32 \times 100}{91}$ $=$*35·16 per cent.*	

If we assume that in forming pillars in the worked-out areas the percentage loss was the same as in the formation of existing pillars, then the percentage coal *in situ* lost during pillar extraction was 35·16—5·15, *i.e.*, 30 per cent. Assuming that 60 per cent. of the coal *in situ* was left in forming pillars in worked-out areas, then the percentage loss of coal during pillar extraction was $\frac{30 \times 100}{60}$ = *50 per cent.*

We may also estimate the percentage of coal *in situ* lost underground during the normal course of working as follows :—

	Million tons.
(*r*) Total quantity of coal lost in worked-out areas . .	32
(*s*) Quantity lost by fires and collapses in worked-out areas	7
(*t*) Quantity assumed to have been lost by theft and as free supply of coal to miners	2
(*u*) Quantity lost underground during the normal course of working . . . . 32—(7+2) =	23
(*v*) Quantity of coal originally present in worked-out areas (*l*)	91
(*w*) Percentage of coal *in situ* lost underground during the normal course of working = $\frac{23 \times 100}{91}$ = *25·28 per cent.*	

From columns 1 and 3 of the table it will be seen that at the close of the year 1927, of the 1,070 million tons of coal originally present 883 million tons remained and of the latter quantity only 734 million tons are of first class quality. In some areas certain sections of 11 and 12 seams give a first class coal the amount of which is estimated to be in the neighbourhood of 100 million tons. The total quantity of first class coal in the field down to a depth of 1,000 feet is, therefore, 834 million tons.

In the year 1927 the output of first class coal from the field was 7·6 million tons of which about $2\frac{1}{2}$ million tons were obtained by the extraction of existing pillars and 5·1 million tons were obtained in the formation of pillars.

At this rate of exhaustion, the life of the first class coal in the field may be estimated as follows :—

	Million tons.
(*x*) Total quantity of first class coal available at present (1927) .	834
(*y*) Total quantity of this coal which is now standing in pillars .	131
(*z*) Total quantity of coal not developed	703

If the percentage loss of coal *in situ* continues at the rate previously calculated (*q*) then 35·16 per cent. will be lost and 64·84 per cent. will be obtained as output.

Of the 703 million tons which has not been developed $\frac{703\times64\cdot84}{100}$ $=455\cdot8$ million tons will be obtained as output.

Of the 131 million tons of coal now standing in pillars 50 per cent. may be lost and 65·5 million tons obtained as output. The total quantity which will be obtained is, therefore, $455\cdot8+65\cdot5=521\cdot3$ million tons. At the rate of output obtaining in 1927, first class coal will be exhausted down to a depth of 1,000 feet in $521\cdot3 \div 7\cdot6 = 68\cdot6$ years.

The losses to date are, however, no measure of the losses which may be incurred in the future, and 68 years is an optimistic figure for the life of first class coal in the field. Experience in India has shown that where the depth exceeds 500 feet it is impossible to extract by the ordinary method of working any large area of pillars in a seam exceeding 20 feet in thickness. Attempts to do so have resulted in collapses and fires. It is chiefly for this reason that there are 131 million tons of coal standing in pillars in the Jharia coalfield. The owners of this coal dare not attempt to extract the pillars without sand packing, and the present price of coal will not allow this method to be adopted. Roughly speaking it may be said that where the depth of a thick seam in India exceeds 500 feet it is impossible to obtain more than 50 per cent. of the coal *in situ* without adopting a filling method.

Unless sand stowing is adopted, a considerable quantity of coal will, most certainly, be lost in the area lying between Karkend and Angarpathra villages where No. 14 and 13 seams are separated by a thin band of shale varying in thickness from 4 to 12 feet only. In this area No. 14 seam is from 25 to 30 feet in thickness and contains about 105 million tons of coal, of which 19 million tons are standing in pillars. In No. 13 seam, the thickness of which is from 18 to 20 feet, there are 86 million tons of coal available and 10 million tons are standing in pillars. Almost all the coal which is standing in pillars in No. 13 seam lies beneath developed workings in No. 14 seam. At several collieries where both seams have been developed, the coal standing in pillars in the lower seam has been lost when attempts have been made to depillar the upper seam. The band of shale separating the two seams is too thin and weak to resist the blow when the roof breaks down in the goaf of the upper seam, with the result that the galleries in the lower seam are filled with debris. If the lower seam had been left solid until mining operations had been completed in the upper seam no coal would

have been lost by this cause. Although this fact is now fully realised by most of the owners, agents and managers operating in this area, it is regrettable to have to record that this shortsighted and wasteful policy is still being continued at several collieries.

The necessity of adopting sand stowing is becoming more and more insistent every year and will become more so in the future. At present the pit head price of coal is so low as to leave only a bare margin of profit even at the best organised and equipped collieries in the field, and the conservation of coal and maximum percentage extraction, which is normally the aim of every mining concern, is sacrificed for large outputs at a minimum cost. When it is considered that sand stowing increases the cost of production by 12 to 20 annas per ton, it is not surprising that the system has not been more generally adopted.

Another result of an increase in the selling price of coal would be an increase in the production of second grade coal and a reduction of that of first grade. In the year 1915 when the boom in the coal trade commenced, the output of first class coal was about 6·8 million tons. From that time as the selling price of coal ascended the output of first grade coal descended until in the years 1921 and 1922, which were at the zenith of the high prices, the output fell to about 3½ million tons. As prices declined the output of first class coal again increased and was 6½ million tons in 1924 and 7·6 million tons in 1927.

These facts show that if the minimum selling price of the different kinds of coal could be fixed so as to permit a reasonable profit and sand stowing be made compulsory where physical conditions make it a necessity, the life of the high grade coking coal in the Jharia coalfield would be increased.

Coking Coal in the Jharia Coalfield.

Number of seam.	Coal originally present within 1,000 feet of surface.[1]	Quantity of coal standing in pillars.	Quantity of coal now available.[2]	Coal lost or sealed off on account of fire.	Coal recoverable from sealed-off areas.	Coal lost by collapses.	Quantity of coal entirely lost.	First class coal available within 1,000 feet of surface.	Quantity of second class and inferior coal.	Quality of coke made from this coal.
	1	2	3	4	5	6	7	8	9	10
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	
18 . .	42,228,000	6,829,000	35,614,000	*Nil*	*Nil*	*Nil*	*Nil*	29,314,000	6,300,000	Fair.
17 . .	54,780,000	6,508,000	39,511,000	*Nil*	*Nil*	*Nil*	*Nil*	39,511,000	*Nil*	Good.
16 . .	114,025,000	3,424,000	108,420,000	*Nil*	*Nil*	25,000	25,000	8,100,000	100,320,000	Fair.
15 . .	209,755,200	34,963,500	159,270,000	4,044,000	965,000	337,000	3,416,000	154,520,000	4,750,000	Very good.
14A. . .	17,723,000	3,673,000	13,099,000	1,312,000	420,000	4,500	896,500	13,099,000	*Nil*	Do.
14 . .	362,741,000	48,835,000	287,758,000	6,641,000	740,000	1,437,332	7,338,332	271,358,000	16,400,000	Do.
13 . .	216,290,000	18,925,700	192,652,000	1,285,000	185,000	717,000	1,817,000	170,952,000	21,700,000	Good.
Thick Seam of Bhowra and Sutik dih Area.	52,446,000	8,210,000	46,756,000	1,720,000	*Nil*	400,000	2,120,000	46,756,000	*Nil*	Very Good.
	1,069,988,200	131,368,200	883,080,000	15,002,000	2,310,000	2,920,832	15,612,832	733,610,000	149,470,000	..

[1] (A deduction of 20 per cent. has been made as an allowance for dykes, faults, barriers, etc).
[2] That is, coal in the solid, coal standing in pillars and coal recoverable from fire areas. (A deduction of 20 per cent. as in column 1 has been made).
NOTE.—In some areas Nos. 11 and 12 seams give a first class coal the quantity of which is approximately 100 million tons.
No attempt has been made to estimate the quantity of coal in the lower seams which are of second class or inferior quality.

COAL LOST BY FIRES AND COLLAPSES IN INDIAN COAL MINES. BY NORMAN BARRACLOUGH, B.SC., *Inspector of Mines in India.*

ATTENTION was first drawn to the losses of coal occurring in the Raniganj and Jharia coalfields by Mr. R. G. M. Bathgate in 1917 when, in his presidential address to the members of the Mining and Geological Institute of India (*Transactions, Mining and Geological Institute of India*, Volume XII), he expressed the opinion that with coal seams of great thickness the losses entailed by wasteful methods of mining amounted to anything between 50 and 75 per cent.

The Government of India taking alarm at the suggested waste of coal decided after consultation with the Governments of Bengal and Bihar and Orissa, the Indian Mining Association and the Indian Mining Federation, to engage the services of a recognised authority on modern methods of extraction. For this purpose the services of Mr. R. I. Treharne Rees were secured. Mr. Rees visited the Raniganj and Jharia fields during the cold weather of 1918-19 and prepared a report which reached the Government of India in August 1919.

The principal recommendation made by Mr. Treharne Rees related to the appointment of an inspecting and controlling authority for the supervision of terms of leases, more efficient methods of coal extraction, including rotation of working a hydraulic stowage, and the more economic use of power and more general employment of electricity.

In January 1920 the Government of India appointed the Coalfields Committee to consider Mr. Rees' report. In its published report that Committee's chief recommendation was that there should be a controlling authority with legal powers designed to ensure conservation and economic extraction. The difficulties which would be encountered in giving practical effect to the recommendations of Mr. Treharne Rees and the Coalfields Committee are, however, almost insurmountable and no tangible results have as yet occurred from their labours.

Attention was again drawn to the subject in a letter written by Mr. R. G. M. Bathgate and published in the Calcutta "States-

man" of the 11th July 1925, and shortly afterwards the Government of India asked the Department of Mines to obtain definite information as to the quantities of coal lost by fires and collapses. An enquiry was instituted and colliery owners, agents and managers willingly co-operated and furnished such information as has enabled an estimation of the quantity of coal lost by fires, etc., to be made with a reasonable degree of accuracy. All mines in the Jharia and Raniganj coalfields where any considerable quantity of coal has been lost were visited and the figures supplied were carefully checked. In the Jharia coalfield where mining operations did not commence until 1894, information about coal lost by fire and collapses has been readily available. In the Raniganj coalfield, however, where coal mining commenced early in the nineteenth century, coal was lost at mines in the Toposi and Muslia areas which were abandoned many years ago. Plans of these areas are not available and in the absence of authentic information it has not been possible to include the quantity of coal lost in the attached table. The quantity of coal lost in these areas, however, would not materially alter the total quantity of coal lost in the field.

In the attached table the quantities of coal lost in the various coalfields are given separately and, as the quantity of second and inferior grade coal in India is almost inexhaustible, a distinction has been made between coal lost in the poorer seams and that lost in the better seams. For this purpose the Indian Coal Grading Board's list of graded coals has been consulted and in the ensuing remarks the standards adopted by the Board are inferred.

In order to interpret correctly the significance of the figures for quantities of coal lost it is necessary to express the quantities as either :—

(*a*) a proportion of the total coal obtained; or

(*b*) a proportion of the coal originally present in the areas from which coal has been extracted.

The former basis in preference to the latter has been chosen for the reasons which follow :—

(1) In all the coalfields there are large quantities of coal standing in pillars in the formation of which little or no coal has been lost, and to estimate the proportion of coal lost on the basis of coal originally present would minimise and give a false impression of the magnitude of the losses.

(2) The quantities of coal obtained from each field can be estimated with accuracy, whereas the estimation of the quantity of coal originally present in areas from which coal has been obtained would be a long and tedious process and the accuracy of the results would be doubtful, as the plans and records of many areas which have been worked and abandoned in the past are not available.

(3) By adopting the former basis similar estimations of the proportion of coal lost in each field can easily and accurately be made periodically throughout the lifetime of each coalfield.

From the figures in the last column in the table it will be noted that the losses of high grade coal in the Jharia and Raniganj coalfields have been 11·48 per cent. and 7·52 per cent., respectively, although the total losses of coal of all kinds in the two coalfields have been 7·52 per cent. and 7·73 per cent., respectively, *i.e.* practically the same. The reason may be explained as follows :—

(*a*) The coal in the Raniganj coalfield is more liable to spontaneous combustion.

(*b*) Mining in the Raniganj field was commenced some eighty years earlier than in the Jharia field, and most of the coal lost was lost in old workings where the quantity of coal removed in the first working was too great and where no precautions had been taken to isolate and guard against fire.

As stated above the proportion of selected and first grade coal which has been lost in the Jharia coalfield is far higher than that lost in the other fields ; the losses of second and inferior grade coal in the Jharia coalfield have been negligible. The poorer grades of coal in the Jharia coalfield have not, up to the present, shown any tendency to fire spontaneously and, as the coal is hard and of a stony nature with unpronounced cleavage planes, practically none of it has been lost by collapses. In the Raniganj field, however, all the seams of coal in the Raniganj stage exhibit almost equal tendency to fire spontaneously, and it is probable that the proportion of second and inferior grade coal which will be lost by fire in the future will equal that of the better grades of coal.

In the Jharia coalfield the greatest losses have occurred in the south-eastern part of the field in the thick seams which outcrop near to the north bank of the Damuda river, and also in an area extending to one mile west of a line running from Lodna village through Bagdigi to Bhulanbarari village. These two areas lie on the flanks of a ridge of metamorphic rocks, and the coal appears to be more strongly cleaved and friable than in other parts of the field. In the former of these two areas about 5½ million tons of coal have been entirely lost as a result of four outbreaks of fire. The two seams in which the fires have occurred have a maximum thickness of 60 and 85 feet, respectively, and are steeply inclined; the coal, moreover, is soft and strongly cleaved. At the mines where these fires broke out the outcrop coal was quarried extensively and when underground mining was commenced innumerable entrances were made from the quarries. Pillars were then formed in several sections of the seams, and sections were generally interconnected in many places. All the fires originated in workings near the outcrops which prematurely collapsed owing to defective methods of mining. Efforts were made to quell the fires but under the conditions related above it is almost impossible to confine and isolate a fire. Experience has shown that when the outcrop of a thick seam of coal has been quarried it is expedient that a solid barrier of coal be left between the quarry and any underground workings which may subsequently be made to the dip.

In both the Raniganj and Jharia coalfields large quantities of coal have been lost because in laying out workings provision was not made by leaving barriers of coal at reasonable intervals to confine any outbreak of fire which might occur to a small area. Moreover, a fire commencing in one mine has, in many instances, eventually involved the workings of neighbouring mines because no barriers had been left between the properties or, if barriers were left, they were too thin to be effective. In one instance a fire commencing in one mine eventually involved four other mines, and in five other cases a fire occurring in one mine spread to adjacent mines.

If proper precautions had been taken the loss of coal by fires and collapses in the Raniganj and Jharia coalfields would probably not have been more than one-tenth of what it has actually been.

Quantity of Coal lost by Fires and Collapses in the Jharia, Raniganj and Giridih Coalfields.

Coalfield.	Grade of coal	Quantity of coal lost by fire or locked up in fire areas.	Quantity of coal locked up in fire areas but considered to be recoverable	Quantity of coal entirely lost by fire	Quantity of coal lost by collapses.	Total quantity of coal lost.	Total quantity of coal obtained from the field.[1]	Quantity of coal lost expressed as a percentage of the coal obtained.
		Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Per cent.
Raniganj coalfield . .	Selected and 1st grade .	11,903,800	3,907,800	7,996,000	1,066,960	9,062,960	120,500,000	7·52
	Second and inferior grade	4,530,000	370,000	4,160,000	83,000	4,243,000	51,500,000	8·24
	TOTAL .	16,433,800	4,277,800	12,156,000	1,149,960	13,305,960	172,000,000	7·73
Jharia coalfield . . .	Selected and 1st grade .	15,002,000	2,310,000	12,692,000	2,920,832	15,612,832	136,000,000	11·48
	Second and inferior grade	*Nil*	*Nil*	*Nil*	100,000	100,000	73,000,000	0·14
	TOTAL .	15,002,000	2,310,000	12,692,000	3,020,832	15,712,832	209,000,000	7·52
Giridih coalfield . .	Selected and 1st grade .	770,000	*Nil*	770,000	122,000	892,000	36,000,000	2·48
	GRAND TOTAL .	32,205,800	6,587,800	25,618,000	4,292,792	29,910,792	417,000,000	7·17

[1] Including coal consumed on the collieries.

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ON THE AGE OF THE ARAVALLI RANGE. BY L. LEIGH FERMOR, O.B.E., D.Sc., A.R.S.M., F.A.S.B., *Officiating Director, Geological Survey of India.*

I.—INTRODUCTION.

In the second edition of the Manual of the Geology of India, Mr. R. D. Oldham draws an interesting parallel between the Aravallis and the Himalayas. The following passage (*Loc. cit.*, p. 103) may be quoted: –

'The north-western boundary of the Vindhyans is in the main a fault of great throw, along which the almost horizontal Bhander sandstone is brought into contact with the highly disturbed Aravalli beds. Beyond this fault there are a few small, but important outliers, composed of the lower members of the system. The largest of these occur south-west of Karauli, where a narrow ridge of Alwar quartzites is faulted against undisturbed sandstones of upper Vindhyan age on the south-east, and on the north-west is overlaid by two alternations of sandstone and limestone, the lower being regarded as lower Vindhyan (Rohtas group) and the upper as Kaimur.[1] The beds have been compressed and are exposed in two narrow synclinals, about 20 miles in length, but there are small outliers of the lower beds to the south-west of Naraoli, as far as the parallel of Ranthambhor.

From just north of Bundi, extending almost to Indargarh, a narrow strip of Kaimur sandstone rests with little disturbance on the slates immediately west of the great boundary fault.

The throw of this fault must be at least 5,000 feet, and there is naturally some difficulty in accounting for a single fault of so great a throw having been formed subsequent to the deposition of the Vindhyans, and among beds which have under-

[1] *Records*, XIV, p. 288, (1881).

gone so little subsequent disturbance as they have. But we will find when treating of the Himalayas that the nature of the boundary between the Vindhyans and the disturbed Aravalli beds is very similar to what we may infer is the contact between the undisturbed deposits of the Indo-Gangetic plain and the disturbed beds of the Himalayas. Moreover, along the foot of the Himalayas, there is a strip of upper tertiary beds which have been disturbed, but to a less degree than the older beds of the range, while the equivalents of these beds are believed to occur under the alluvial plain, in perfectly conformable sequence with the most recent alluvium. Now, if these suppositions are correct, as is almost certainly the case, we can imagine that, after ages of denudation, the upper tertiary rocks of the Siwalik zone will be almost removed, and the northern boundary, of what is now known as the Indo-Gangetic alluvium, will then exhibit very much the same features as the boundary of the Vindhyans towards the Aravalli range now does. The upper beds will be in contact with highly disturbed rocks of much more ancient date along a great line of fault. Beyond this will be a few outliers composed of the lower beds of the series, the Siwaliks of the present classification, and to the north of these there will be a broad exposure of the wreck of a mountain range.

In the case of the Himalayas the fault has been gradually formed *pari passu* with the deposition of the Indo-Gangetic alluvium, which is contemporaneous in its origin with the principal elevation of the Himalayas and formed of the debris of that range.

It is natural to suppose that the similar structure in the case of the Aravallis indicates a similarity of origin and that the great Vindhyan spread of Central India is formed of deposits which bore the same relation to that range as the Indo-Gangetic alluvium does to the Himalayas.

The suggestion is an important one since it would fix the period of the formation of the Aravalli range, or at any rate of its principal importance, as contemporaneous with the deposition of the upper Vindhyan rocks that were formed of its debris. It would account for the greater prevalence of sandy beds near this margin of the deposit and would place the original limit of deposition not very far beyond the present limit of the outcrops.'

In the foregoing passage Mr. Oldham regards the period of the principal formation of the Aravalli range as Upper Vindhyan, and this view is not at variance with that expressed on page 492 of the Manual that :—

'The Vindhyan epoch is the age to which the rise of the Aravallis and the demarcation of the east coast has been ascribed.'

However, the author evidently regards the age thus ascribed to the uplift of the Aravallis as not beyond doubt, for on page 491 he remarks :—

'The close of the Cuddapah epoch appears to have witnessed the commencement of the earliest of those earth movements whose effects on the surface contours and geography of India are still prominently noticeable. It was then that the great mountain range, of which the present Aravallis are but the wreck, was raised, and extending far beyond its present limits, stretched across what is now the Gangetic plain, possibly even to the Himalayas.'

Further, on page 6 he remarks:—

'The Aravalli differs from the other great ranges of India in being entirely composed of disturbed rocks, with axes of disturbance corresponding with the direction of the chain. The formations found in the Aravalli range belong to the transition rocks, and are of great antiquity; for the most part they are much altered, they are quite unfossiliferous, and there is evidence which renders it probable that the elevation of the range dates from a period anterior to the deposition of the Vindhyan rocks, themselves of unknown age but almost certainly not of later date than carboniferous, whilst the fact that these Vindhyan rocks are found almost horizontal in the neighbourhood of the Aravalli range, on both sides of the chain, shows that here, as elsewhere in the Peninsula, the forces which have affected the extra-peninsular area in later geological epochs have not been felt.'

In the Manual, therefore, the period of principal upheaval of the Aravalli range is variously referred to (1) as contemporaneous with the deposition of the Upper Vindhyan rocks, (2) the close of the Cuddapah epoch and (3) as dating from a period anterior to the deposition of the Vindhyan rocks.

Of the three views advanced, Mr. Oldham evidently favours the first, although nowhere does he discuss the three together.

We may perhaps assume that Mr. Oldham considered that the period of upheaval of the Aravallis commenced at the close of the Cuddapah epoch, and continued during the deposition of the Vindhyans, the principal importance of the Aravallis being attained concurrently with the deposition of the Upper Vindhyan rocks.

In addition, he ascribes to the Aravallis a characteristic said not to be possessed by any of the other principal mountain chains of the Indian Peninsula; this can be seen from the following passage (*Loc. cit.*, p. 5):—

'This remarkable absence in the Indian Peninsula of any evidence of disturbance in late geological times—a feature which abruptly distinguishes the whole area from the remainder of Asia—will be further noticed in the sequel; at present it is sufficient to remember that the principal mountain chains of the Indian Peninsula are, with one exception, not coincident with axes of disturbance or elevation, and to note the contrast in the extra peninsular area'.

Then follows the passage on page 6 quoted above, from which it is seen that the one exception is the Aravallis, which are thereby again implicitly compared with the Himalayas. These two passages on pages 5-6 summarise the discussion on pages 3-5, in which the various mountain ranges of the Peninsula are noticed in turn, including ranges which in the light of more modern knowledge must be regarded as having a linear extension coincident with axes of disturbance or elevation. Thus the Godavari-Mahanadi section of

the Eastern Ghats, in which this coincidence exists, and which orographically are as important as the Aravallis, and which are now known to be constituted of charnockites, khondalites and garnetiferous gneisses, are referred to (p. 4) as 'the south-eastern scarp of the Bastar-Jaipur plateau, north-west of Vizagapatam,' which is composed of entirely different rock formations.

Of recent years steady systematic work has been in progress in Rajputana and Central India, first under the superintendence of Mr. C. S. Middlemiss and then under that of Dr. A. M. Heron. Dr. Heron has also been the most active worker in that region; and from his pen is now appearing a series of careful descriptive memoirs, which are models of how such work should be done and a mine of information to every one interested in the old crystalline and schistose rock systems of India. A large portion of Dr. Heron's work has lain in the Aravalli range and adjoining country, and it has, therefore, become necessary for him to give consideration to the question of the time of elevation of this range, and the correlation of the various divisions recognised in the old schistose formations with the schistose formations of other parts of India. Dr. Heron's views are contained in Chapter XI of his memoir on 'The Geology of North-Eastern Rajputana and Adjacent Districts' [*Mem. Geol. Surv. Ind.*, XLV, Pt. 1, (1917)].

In discussing therein the period of upheaval of the Aravalli range (pp. 112, 113), Dr. Heron quotes at some length the passage in which an Upper Vindhyan age is ascribed to this period of upheaval. Dr. Heron himself expresses the opinion that there was a close connection between the upheaval of the Aravalli range and the outpouring of the Malani rhyolites, and that whether these lavas be of Delhi or Lower Vindhyan age, 'their age would be quite consistent with Oldham's suggestion that the Aravalli mountains arose during the deposition of the Upper Vindhyans.' (*loc. cit.* p. 114) [1]. He also adopts the views in the Manual, already quoted, ascribing to the Aravalli range the special property of being the only mountain range of the Peninsula composed of folded rocks in which the axes of disturbance correspond with the direction of the range, and does not note the case of the Godavari-Mahanadi section of the Eastern Ghats referred to above, which he considers to be

[1] From these passages the reader is apt to conclude, as I did, that Dr. Heron himself adopts Oldham's views just quoted. But I find that Dr. Heron is now of opinion that the age of the range is pre-Vindhyan.

much less extensive than the Aravalli range. The less important, but certainly definite, ranges of Singhbhum, the Satpuras and the southern section of the Western Ghats may be cited as other cases in which we now know that there is a definite relationship between axes of folding and direction of ranges.

In discussing the age of the rocks which he describes under the title of the Delhi System, Dr. Heron (p. 112) is thus led to suppose that whilst the Delhis 'have their approximate equivalents in other parts of the Peninsula', they 'have been folded in this particular area alone by movements which were absent or insignificant elsewhere'. He considers that the Delhis are a post-Archæan formation, and therefore, post-Dharwar in age. To me, however, they appear to be lithologically similar at least in their more highly metamorphosed facies to rocks treated as Dharwarian in other parts of India, and special proof appears, therefore, to be necessary that the Delhis are of Purana age.[1]

When a writer draws attention to the parallelism between axes of folding and strike of mountain ranges, the idea is at once suggested, even if not explicitly mentioned, that the elevation of the range and the folding of the rocks that constitute it are contemporaneous events. This view suggested by Oldham appears to have been adopted by Dr. Heron with reference to the Aravalli range, so that the impression is given to the reader that out of two possibilities considered (pp. 111-112) the author prefers the view that the Delhis are roughly contemporaneous with the Cuddapahs, and that they have been folded in this particular area by movements that were absent or insignificant elsewhere, and movements that have caused, at least in part, the prominence of the Aravalli chain due to uplift with the ultimate production of the Vindhyan boundary fault. For this and other reasons Dr. Heron regards the

[1] The geological problems of Rajputana have become somewhat obscured by changes of nomenclature, so that the terms Delhi and Aravalli do not always indicate precisely the same geological formations in Indian geological literature. In some cases Hacket's original nomenclature has been followed either tacitly or explicitly and in other cases his later nomenclature as modified by Heron. Thus the term Aravalli as used by myself [*Mem. Geol. Surv. Ind.*, XXXVII, pp. 282-283, (1909)] and Vredenburg ['Summary of the Geology of India,' first edition, p. 15, (1907)] has a different scope from that later adopted by Heron in the memoirs cited. The latter is that now officially adopted by the Geological Survey of India, and to prevent further confusion it is important to follow Heron in the application of the terms Delhi, Raialo and Aravalli to the geology of Rajputana. As this paper is concerned with a discussion of the origin of the Aravalli orographical unit, and as the Aravalli range is only partially built up of the Aravalli formation, I have, for the sake of clarity, used the term Aravalli only in its geographical sense, referring simply to all the formations older than the Delhis as Pre-Delhi.

Delhis as belonging to the Purana group of formations rather than to the Archæans.

The importance of normal faulting and horst-uplift in the elevation of ranges is only now beginning to be understood, so that we must accept as a logical possibility that such a range as the Aravallis could have been elevated as a folded mountain chain, base-levelled by erosion, and then at a later period elevated again by faults parallel to pre-existing structures without any serious degree of concomitant and additional folding and metamorphism of the rocks of the range. The Aravalli-Vindhyan boundary may consequently be of this nature.

In view, therefore, of the additional knowledge concerning the geology of India that we have obtained since the publication of the last edition of the Manual, and in view of the possible truth of views other than those advanced by Oldham and Heron concerning the interpretation of the geology of Rajputana as adumbrated above, it appears to me desirable to re-examine, in the light of Lake's rule for the angle of the thrust-plane at the edge of an overthrust mountain range (see the following paper), the validity of the parallelism between the Himalayas and the Indo-Gangetic alluvium, and the Aravallis and the Vindhyans, as sketched by Mr. R. D. Oldham in the Manual of the Geology of India.

This I propose to do as briefly as possible.

II.—VALIDITY OF THE COMPARISON OF THE ARAVALLIS WITH THE HIMALAYAS.

If the agreement between theory and observation as applied to the Himalayas brought to notice in the following paper be anything more than fortuitous, it follows that we can use Lake's rule to test the probable truth of the interpretation of an hypothesis devised to explain the relationship between another mountain range and its adjoining lower ground, though obviously one should not lay too much stress upon the exact angle of dip, but be content with approximate agreement between threory and observation.

We will discuss the parallel drawn by Mr. R. D. Oldham between the relationship of the Himalaya mountains to the Indo-Gangetic alluvium at their foot and the relationship of the Aravalli mountains to the Vindhyan tract to the south-east. For this comparison to be completely valid, the following conditions satisfied by the

Himalayas and Indo-Gangetic alluvium must be satisfied by the Aravallis and the Vindhyans :—

(1) The mountain range (the Aravallis) must be convex towards the lower-lying younger sedimentary tract of Eastern Rajputana and Central India (the Vindhyans).[1] (2) The boundary fault between the formations constituting the mountain range and the lower-lying tract must show an angle of dip in the direction of the mountain range, and the amount of this angle should be deducible from the curvature of the range. (3) As the hypothesis involves the view that the lower-lying Vindhyans are comparable in origin with the alluvial deposits of the Indo-Gangetic tract as having been derived from the degradation of the mountain chain they should show a similar lenticular and inconstant character with, on the whole, a coarser facies close to the mountain chain.

We may now take these points in order.

(1) The first condition is not satisfied, because the Aravalli mountain tract instead of having a curvature convex towards the Vindhyan tract of Eastern Rajputana and Central India is concave thereto, the strike of the rock folds changing from N.E.-S.W. at the northern end of the range, to N.N.W.-S.S.E. at the southern end.

(2) It is known that there is a fault of large throw (estimated at 5,000 feet) separating the Aravalli tract from the Vindhyan tract. The nature of this fault is unknown, on account of absence of exposures of the actual fault plane. In the sections accompanying his last memoir (1922) Dr. Heron shows (Plates 38 and 39) the Great Boundary Fault as a nearly vertical normal fault hading to the south-east or down-throw side (though in one text figure page 170, he indicates an opposite hade at a point intermediate between two of his plate sections). A similar hade is shown in the parallel main fault extending from near Achnera to Malarna.[2] In spite of the representation of these faults as normal ones, it appears from the text of Dr. Heron's memoir that they are not simple tensional faults, for there is ample evidence of compression in the form of brecciation and tilting of the Vindhyans at and in the neighbourhood of the fault. Mr. Coulson [3] in his account of

[1] Only the north-western edge of this tract of Vindhyans including the boundary fault, is in Rajputana ; the major portion is in Central India.

[2] For a diagrammatic section of this second fault plane as exposed in the Malarna hills, see Heron, *Mem. Geol. Surv. Ind.*, XLV, p. 140.

[3] *Rec. Geol. Surv. Ind.*, LX, pp. 164-204.

the geology of Bundi State, which is traversed by the continuation of the section of the Great Boundary Fault described by Dr. Heron, represents this fault in his sections as a reversed fault hading to the Aravalli or north-west side. This change of opinion is not supported by the discovery of any sections exposing the fault, and is made, I understand, on general grounds with which Dr. Heron concurs and presumably in deference to the compressional phenomena to which reference has just been made. A study of the sections appearing in the text of Mr. Coulson's paper suggests to me that in Bundi the Vindhyans have been arched into an anticline by compression against the older rocks along the Boundary Fault and that subsequently this arch has collapsed with the resultant subsidence of the Vindhyans along normal fault planes. Figures 4 and 6 of Mr. Coulson's paper represent the arching at points where collapse has not followed, figures 3 and 7 indicate the method of collapse at two ends of the collapsed belt, and figures 1, 10 and 5 indicate the method of collapse of the north-west limb of the arch at intermediate points, the south-east limb of the arch being missing. On this interpretation it would be more natural to show the Boundary Fault in these sections as hading to the south-east, the turning down of the Vindhyans against the fault, represented in figures 4 and 5, indicating a slight overthrust of the Vindhyans on to the older rocks up a steeply inclined plane of thrust. This interpretation is not, however, free from difficulties, because the final net effect is a large downthrow to the south-east of the Vindhyan tract with reference to the Aravalli tract, so that the interpretation just suggested would require first a large downthrow to the south-east along a fault plane hading steeply to the south-east, stresses then being tensional; next a compressive force arching up the Vindhyans against the Boundary Fault with some movement of the Vindhyans up this fault (*i.e.*, some overthrust of the Vindhyans on to the older rocks), followed by further tensional forces, or a release of pressure, with resultant collapse of the arched area. The process could be looked at more simply if the Boundary Fault be regarded as hading steeply towards the older rocks, and the uplift of the Aravalli tract as having produced a measure of overthrust on to the Vindhyans with resultant arching of their margin followed by collapse on removal of the compressive forces. The only difficulty against accepting this interpretation is that the Bundi details seem to favour an overthrust of the Vindhyans on

to the Aravalli tract. On the whole, it is safer at present to represent the Boundary Fault as vertical. In considering the nature of this fault it is important to remember that it is not a simple fault and in detail is, according to Dr. Heron, sometimes represented by a faulted belt. It tends also to bifurcate at points of sharp change of direction, the shorter branch continuing the previous direction of the fault.

Later in this paper it will be seen that the Aravalli tract is regarded as a horst, on which view the Aravalli tract may be treated as an example of Kober's *Horst-(Schollen)-gebirge* or horst-mountains.[1] According to Kober, the formation of a '*Schollenfeld*'[2] is due to an 'undulation' associated with fractures, overthrust and the formation of troughs, basins, and blocks. The blocks that are carried upwards well over (*Uberquellen*) the sunken tracts so as to produce marginal overthrust: but great overthrusts are completely missing. A characteristic of horst mountains is that they have been formed by dissection of an uplifted peneplain. Remnants of such a peneplain have been detected in the Aravalli tract by Dr. Heron (see footnote, page 402), so that if we adopt the view advocated later that the Aravalli tract is a horst, then, following Kober, the Great Boundary Fault should show a moderate degree of overthrust of the Aravalli tract on to the Vindhyan tract. This would require a steeply dipping thrust plane hading to the Aravalli side.

Summarising, we may say that such evidence as there is appears to favour the view that the Great Boundary Fault is a fault of moderate overthrust. The details of the Bundi evidence suggest that the overthrust is of the Vindhyan tract on to the Aravalli tract, whilst a consideration of the problem from the general point of view has led Dr. Heron to regard this overthrust as of the Aravalli tract on to the Vindhyans, and this view is in accord with Kober's descriptions of the general phenomena accompanying horst mountains. In any case, the evidence appears to require that the angle of dip of the fault is a steep one. But if the Aravalli-Himalayan parallel is to be maintained, this angle should be so small as to be less than 14°; for the curvature of the Aravallis is such that if they

[1] L. Kober, 'Der Bau der Erde', pp. 82-84, (1921).

[2] It is difficult to find a suitable English word for 'Scholle'. The literal translation is 'clod,' and evidently it means a portion of the crust detached on one or more sides by faults; perhaps 'block' is the suitable term.

were comparable with the Himalayas, the angle of this thrust plane would be still smaller than that of the Himalayan Boundary Fault.

(3) The third test is that the strata composing the Vindhyan formation should show an inconstant lateral extension and rapid downward alternation and variation comparable to the characters possessed by the Indo-Gangetic alluvium. One of the most striking characters, however, of the Vindhyan formation is the distinctness of the horizons or stages into which it can be sub-divided, and the great distances over which many of the stages can be traced on lithological grounds, so that separate names can be attached to each.[1] The fact that one of these stages consists of an important limestone persistent over large areas, and that other stages consist of definite shales, and others of definite sandstones, is also in violent contrast with the composition of the Indo-Gangetic alluvium, as represented either by the alluvium itself or by the older Siwalik rocks, which, for the purpose of this discussion, must be regarded as the earlier-deposited portions of the Indo-Gangetic alluvium. In particular the Indo-Gangetic alluvium and the Siwaliks are remarkably free from limestone, the calcareous element being represented only by kankar nodules.

It appears, therefore, from the considerations just advanced that the comparison drawn by Mr. Oldham between the relationships of the Himalayas to the Indo-Gangetic alluvium on the one hand and of the Aravallis to the Vindhyans of Central India on the other hand breaks down completely on the points discussed (but see pages 404 & 408), and that, therefore, this argument is not available for use in discussing the formation of the Aravallis as a mountain range. This conclusion is reinforced by the fact that not only do the Vindhyan rocks crop out on the south-eastern side of this range, but also in Western Rajputana to the north-west.

Mr. Oldham in the Manual (p. 106) referring to this point writes :—

'But, on the hypothesis of the relation between the Aravalli range and the Upper Vindhyan sandstones which has been proposed above, there can never have been any continuity between the outcrops on either side, and it is incorrect to

[1] I am, of course, speaking broadly. It is recognised that there are lateral variations in coarseness of certain Vindhyan horizons, and that certain strata (*e.g.*, the Bijaigarh shales of Mallet) do not persist throughout the whole extension of the Vindhyan formation.

speak of the Jodhpur beds as outliers of the Vindhyan basin. They must have been formed contemporaneously in an independent basin of deposition, and the connection between the two would be similar to that which subsists between the recent deposits north of the Himalayan range and the Indo-Gangetic alluvium'.

On this point one must remark that whereas the Vindhyans of Jodhpur are at a somewhat lower level than those of Eastern Rajputana and Central India, the recent deposits north of the Himalayan range are at an elevation of some 12,000 feet above the Indo-Gangetic alluvium.

From the above we see that it is very difficult to regard the north-western boundary fault of the Vindhyan tract of Eastern Rajputana and Central India as comparable with the Main Boundary Fault of the Himalayas and still more difficult to suppose that there can have been an important overthrust of the Aravallis on to the Vindhyans. This means that although the Vindhyan boundary fault is one of great importance, it cannot be treated as a fault of the type that might have been associated with the important folding and often intense metamorphism exhibited by the older Delhi strata. The main folding and metamorphism of the Delhis must instead be of vastly greater antiquity than this fault.

III.—THE REJUVENATION OF THE ARAVALLIS.

Having shown that there can be no close parallelism between the Vindhyan boundary fault and the Himalayan boundary fault, we are now in a position to consider anew the origin of the Aravalli range.

Although it has been shown above that the Himalayan-Aravalli comparison cannot be maintained in the form in which it was originally propounded by Oldham, yet the Aravalli-Vindhyan boundary fault does provide cogent evidence of a differential movement of the Aravallis with reference to the Vindhyans of Eastern Rajputana and Central India. The throw of this fault is taken as 5,000 feet in the Manual and this figure is adopted for the purposes of this paper. Now, the Vindhyans of Western Rajputana on the opposite side of the Aravallis must have been deposited at the same approximate level as the Vindhyans of similar age on the Eastern Rajputana side, for, after all, there seem to be good reasons for supposing that at least a portion of the Vindhyans was deposited under marine conditions. The Vindhyans of Western Rajputana

are referred by Hacket[1] to the Kaimur and Bhander sub-divisions of the Upper Vindhyans, the middle (Rewa) division of the Upper Vindhyans being apparently absent. These views are accepted by La Touche[2] in his account of the geology of this region: but I gather from Dr. Heron that he regards Hacket's correlation of the Western Rajputana Vindhyans with the Kaimur and Bhander as very dubious, and that the Jodhpur rocks may be either Upper or Lower Vindhyans, but that correlation with sub-divisions fails. Vredenburg[3], however, was prepared to correlate one horizon (the Purple Sandstone) in the Salt Range with the Kaimur or Rewa Sandstone. In view of the conflict of opinion on this point, all we can safely say is that on the eastern side of the Aravalli range, the Vindhyans lie at a somewhat higher level than in Western Rajputana.

From this we may deduce that if we accept, on the evidence of the Aravalli-Vindhyan boundary fault, a differential upward movement of the Aravalli tract of some 5,000 feet with reference to the Vindhyan tract of Eastern Rajputana and Central India, we must also accept as a possibility a differential movement of the same order of magnitude of the Aravalli tract with reference to the Vindhyans of Western Rajputana. This means that, in addition to the observed eastern boundary fault of the Aravalli tract, we must admit the possible existence of another western boundary fault somewhere to the west of the western foot of the Aravalli range. I am not aware of any observations proving the existence of such a fault; but the acceptance of its existence seems difficult to avoid,[4] with its corollary that the Aravalli tract must be regarded

[1] *Rec. Geol. Surv. Ind.*, XIV, p. 301.

[2] *Mem. Geol. Surv. Ind.*, XXXV, pp. 26-28, (1911).

[3] *Vide* 'Summary of the Geology of India,' second edition, p. 36, (1910).

[4] Unless we imagine a tilt of the Aravalli tract about a hinge line along the western foot of the range. This appears to me a less probable hypothesis, because of the fact that the Aravallis curve from S. W. to S. E. at their southern end. It will be found, however, by those who prefer a tilt to a horst that the substitution of tilt for horst will not affect the conclusions drawn in in this paper. A tilt would appear to preclude the Vindhyan boundary fault from being treated as a reversed fault. In the level summits of the ridges in Alwar and Jaipur Dr. Heron has recognised a raised peneplain [*Mem. Geol. Surv. Ind.*, XLV, p. 8, (1917)] which he has since found continuing through Ajmer-Merwara and the Mewar (Udaipur) State, maintaining about the same level as far southward as surveys have so far proceeded. Dr. Heron suggests to me that this elevatéd peneplain might conceivably be the ancient base-level of erosion of the range previous to rejuvenation. If this were so, it would, of course, render impossible the acceptance of the idea of a tilt unless the peneplain itself could be shown to be tilted. Mr. Middlemiss has suggested that this peneplain might be traced southwards so as to fall to the level of the Ahmednagar sandstone of Umia

as a horst, in which an already folded tract of country has been uplifted along fault lines parallel to pre-existing structural trend lines. At the south-western end of its course, the eastern boundary fault curves from south-west to south-south-east. It will be interesting to discover, when detailed geological survey work reaches the south-western end of the Aravalli region, whether the hypothetical western boundary fault must be regarded as also curving to the south-east.

If we accept this conclusion that the Aravalli tract must be regarded as a horst with an uplift of some 5,000 feet relative to the lower country on both sides,[1] we must next consider the date of production of this horst. For this, three possible explanations present themselves :—

(A) The elevation of the range is entirely post-Vindhyan, in which case the Vindhyan rocks of Western Rajputana were deposited in continuity with those of Eastern Rajputana and Central India, resting, in the present Aravalli tract, upon the upturned edges of the Delhi and pre-Delhi rocks. This hypothesis has two variants :—

(1) The Delhi rocks, although already folded and metamorphosed in pre-Vindhyan times had not yet been elevated to form a mountain range.

(2) The old complex of folded Delhi and pre-Delhi rocks had previously been elevated to form a mountain chain and had already been base-levelled by long-continued erosion before the deposition of the Vindhyans.

(B) The range was formed originally in pre-Vindhyan times and had not been completely base-levelled by the commencement of Vindhyan times, so that it acted as a barrier separating partially or completely the western from the eastern areas of Vindhyan

(Cretaceous) age [*Mem. Geol. Surv. Ind.*, XLIV, p. 142, (1923)] and if this were so, it might be possible to ascribe a Cretaceous age to the rejuvenation of the Aravallis. Such an attribution would, however, conflict with Dr. Fox's requirements of a pre-Gondwana Aravalli range, unless we suppose two periods of rejuvenation since Vindhyan times, of which Dr. Heron's peneplain would then represent the later. The peneplain detected by Dr. Heron does not seem to be high enough to be ascribable to pre-Vindhyan or Vindhyan times. Any such early peneplain must have been removed long ago, and Dr. Heron's peneplain on this view would then indicate a second and later period of rejuvenation. According to Kober, 'Der Bau der Erde,' p. 82, (1921), dissected peneplains are characteristic of horst-mountain tracts.

[1] It is not here maintained that the amount of throw is the same on both sides of the horst. Western Rajputana may or may not be displaced in a vertical sense, with reference to Eastern Rajputana. This is a matter for separate discussion when necessary.

deposition [1]. On this hypothesis the present elevation of the range is due to relative uplift in times which may have been partly contemporaneous with the deposition of the Vindhyans as supposed by Oldham, and partly subsequent, and to this extent the parallelism between the Aravallis and the Himalayas can be sustained.

Let us now discuss briefly each of these possibilities.

The fact that strata cannot be severely folded without suffering compression into a smaller width of outcrop, and without the necessary protuberance upwards of alternate folds, shows that the Delhis could not have been thrown into their present folded condition without the formation of a mountain chain.[2] Therefore we need not consider further possibility A(1). The choice therefore reduces itself to A(2) and B, both of which hypothesis require us to accept the logical necessity of an Aravalli range of pre-Vindhyan age, and to regard the present range as the remains of this pre-Vindhyan range rejuvenated in post-Vindhyan [hypothesis A(2)] or Vindhyan (hypothesis B) times. On hypothesis A(2) this range was base-levelled in Vindhyan times, covered by a continuous spread of Vindhyan deposits, and re-elevated (relatively speaking) in post-Vindhyan times as a horst along faults following pre-Vindhyan structural lines. On hypothesis B the Aravalli range was never completely base-levelled so as to be covered completely by Vindhyan deposits, and the additional elevation of the range may have taken place along the two boundary faults, *pari passu* with the deposition of the Vindhyan sediments on either side.

I confess myself unable to choose with certainty between these two hypothesis. On hypothesis A(2) the rejuvenation of the Aravallis is logically entirely post-Vindhyan; and as the Aravalli range was probably already in existence by Talchir times—the existence of such a range appears to be required by the facts of Gondwana geology [3]—we should then be able to ascribe this rejuvenation to

[1] On this hypothesis there must nevertheless have been in Vindhyan times some connection between the western and eastern areas of deposition, if any stages (*e.g.*, Bhander and Kaimur) can be recognised on both sides of the range (for the different opinions on this point see page 402).

[2] The original height of this chain may have been less than might at first be supposed, because the compression of a certain volume of strata into a narrower tract would cause overloading of that strip of the earth's crust relative to adjoining tracts with consequent partial sinking, unless isostatic readjustment were produced by flow of magma below from one sector to another, accompanied by suitable volume changes in the upper portion of the infra-plutonic shell.

[3] Dr. Fox, who is engaged in a close study of the facts of Gondwana geography and geology, hopes to discuss this point at a suitable opportunity.

the interval between Vindhyan and Talchir times. Light might be thrown on the problem by one with a detailed knowledge of the facts of lateral variation in lithological composition of Vindhyans.

If, however, the more ancient Aravalli range persisted into Vindhyan times, as required by hypothesis B, so that the Aravalli tract was never completely covered by Vindhyan deposits, then shore-line conditions should be exhibited in the Vindhyan strata on both sides of the Aravalli tract. In the Manual it is suggested that evidence of such shore-line conditions exist on the eastern side, but the evidence does not seem conclusive. Thus, there is no concentration in the Vindhyan tracts marginal to the Aravalli region of bands of coarse conglomerate analogous to the Siwalik conglomerates.

There are differences between the eastern and the western tracts of Vindhyans that may help us. In Eastern Rajputana and Central India not only is there a complete sequence of Upper Vindhyan stages down to the Kaimurs, the usual base of the Upper Vindhyans, but below the Kaimurs are the beds of Jhalra Patan and Nimbahera, which pass conformably up into the Upper Vindhyans and are regarded by Dr. Heron as an integral part of the Upper Vindhyans,[1] and by Drs. Heron and Fox as the equivalent of certain Upper Vindhyan beds occurring below the Kaimurs at Bijaigarh in the Mirzapur district, U. P. In addition, there are the Lower Vindhyan beds of Karauli [2] in Eastern Rajputana.

In Western Rajputana, on the other hand, on Hacket's interpretation, the Lower Vindhyans are completely missing, and a conglomerate passing up into sandstone regarded by Hacket as Kaimur is seen resting upon older rocks. The Rewa (middle) subdivision of the Upper Vindhyans is missing, but the Bhander subdivision is represented. Further, if we accept the tract occupied by the Vindhyans as shown in Mr. La Touche's map of Western Rajputana, with the additional tracts to the north-east mentioned in the corresponding text,[3] as representing the whole of the Western Rajputana tract of Vindhyans, then we might be inclined to favour

[1] It is in the Suket shales, one of the sections of these sub-Kaimur Upper Vindhyans near Neemuch, that Mr. H. C. Jones discovered the fossils that have been recently accepted by American palæontologists as recalling the Cambrian brachiopod *Acrothele*. See *Rec. Geol. Surv. Ind.*, LX, p. 18, (1927). It must be mentioned, however, that more recently, another American palæontologist has expressed the opinion that these remains are plant and not animal fossils.

[2] Heron, *Mem. Geol. Surv. Ind.*, XLV, pp. 45-58, (1922).

[3] *Mem. Geol. Surv. Ind.*, XXXV, pp. 26-30, (1911).

the view that the Western Rajputana tract was once joined to the Central Indian tract, and that the area of deposition of the Vindhyans gradually increased owing to the gradual sinking of the basin of deposition so that the Upper Vindhyan strata overlapped on to older pre-Vindhyan strata in Rajputana. On this view the once-continuous area of Vindhyans had its north-western edge detached from the main area by a post-Vindhyan Aravalli uplift. The alternative to this is expressed in the following quotation from La Touche (*loc. cit.*, p. 29):—

'All we can say is that towards the end of the Vindhyan period a local depression was formed on the western side of the Aravallis, in which these sandstones and limestones were deposited.'

On this view it might prove difficult to effect any correlation between the strata on the two sides of the range (see also footnote, p. 404).

It is not certain, however, that the most northerly exposures of Vindhyans in Rajputana (40 miles north-east of Bikaner) indicate the limit of deposition of this formation to the north; for beyond this point all the rocks are covered by sand and the Indus alluvium,[1] until the Salt Range is reached. In this range are strata of Cambrian age that have been regarded by Vredenburg [2] as lithologically indentifiable with Vindhyan rocks. In view of the Cambrian affinities of the fossils from Neemuch (see footnote, p. 405), we are bound to give much weight to Vredenburg's opinion on this point. Further, to the west of the Barmer and Jodhpur tract of Western Rajputana, we find post-Vindhyan rocks and then the Indus alluvium, so that it is possible that the Vindhyan area of deposition continued in this direction also.[3] If we admit this much wider area for the Vindhyan rocks west of the Aravalli range, it is no longer possible to treat the known exposures of Western Rajputana as representing merely the western end of the Vindhyan basin.

Greater precision on this question is at present impossible, and we are compelled to leave to the future the definite choice between hypothesis A(2) and B. This may become possible with the acquisition of further data on the details of the geology of Rajputana and

[1] Except for the pre-Vindhyan rocks of the Kirana Hills.

[2] Summary of the Geology of India, 2nd Ed., p. 36, (1910).

[3] Dr. Fox in his recent paper on the Geology of the Punjab Salt Range [*Rec. Geol. Surv. Ind.*, LXI, p. 174, (1928)] adopts the view that the Cambrian strata of the Salt Range may prove to be equivalents of the Upper Vindhyans. and also of the Hormuz Series of Persia.

Central India, and it may even be possible now for Dr. Heron, with his intimate knowledge of portions of this region, to show which of these two hypotheses should be adopted.[1]

IV.—CONCLUSIONS.

Although it has been necessary to leave the problem of the age of the Aravalli range partially unsolved, yet we can with a fair amount of confidence affirm the following conclusions :—

(1) That the original Aravalli range was a fold-range of pre-Vindhyan age.

(2) That the range was eroded and either partially or completely base-levelled in pre-Vindhyan times.

(3) That the range has been rejuvenated as a horst along a pair of roughly parallel boundary faults.[2]

(4) That if the base-levelling was so complete that the area of deposition of Vindhyan rocks extended continuously over the present site of the range from Western Rajputana to Central India, then the rejuvenation took place in post-Vindhyan, but pre-Talchir times.

(5) That if the base-levelling was less thorough, so that the remnants of a mountain range persisted up into Vindhyan times so that the western and eastern areas of Vindhyan deposition were partially separated by the Aravalli range, then the rejuvenation by uplift along boundary faults may have been post-Vindhyan, as with conclusion (4), but is more likely to have taken place *pari passu* with the deposition of Vindhyan sediments in the two areas, owing to the necessity of isostatic readjustment to meet the change of load. To this extent we are then in

[1] Dr. Heron informs me that he favours B with reservations. He remarks that the main difficulty appears to be the absence of shore-conglomerates in the Fatehpur-Sikri-Chitor-Jhalrapatan lobe of the Eastern Vindhyans, but that light may yet be thrown on this when the ground is resurveyed. Meanwhile, Dr. Heron has suggested that the shore deposits may have existed on the upthrow, Aravalli, side of the Great Boundary Fault, and have been removed since the fault was produced, or *pari passu* with its production. Again, if we accept two suggestions of Dr. Fox, (*a*) that the deposits making up the Vindhyans come from the east and (*b*) that the Salt Range and S. W Persia formed a region of severe desiccation in early Cambrian (*i.e.*, early Vindhyan) times, we might deduce that the amount of detritus yielded by the Aravalli range was small compared with that from the east, and that under the arid conditions presumed, it did not take the form of torrent-carried conglomerates, but of finer insolated and wind-borne material.

[2] Or by means of a tilt.

agreement with the views of Oldham, and to this extent the comparison with the Himalayas and Indo-Gangetic alluvium holds.

(6) In addition to the pre-Talchir period of rejuvenation, there are possible signs of a later period of rejuvenation on a smaller scale, in the peneplain detected by Dr. Heron in Alwar, Ajmer and Udaipur.

There is not sufficient evidence to enable us to choose between (4) and (5); but because an explanation can be given of the cause of the uplift if we adopt conclusion (5), and on the grounds of greater probability, I am inclined to favour (5) rather than (4); but we must be prepared for the possibility that future work may bring to light evidence justifying our conversion to hypothesis (4).

I do not propose to discuss here the age of the earlier Aravalli range and the exact period of the movements that produced both such earlier range and the folding and metamorphism of the Delhi strata, because such problems will be more suitably discussed as a part of the treatment of the old schistose formations of India as a whole. I shall be satisfied here if this paper be accepted as providing sufficient reasons for regarding the *main* folding and metamorphism of the Delhis as definitely pre-Vindhyan, and not connected with the earth movements that have led to the rejuvenation of the Aravalli mountain system along the boundary faults referred to in this paper. It is not suggested that no folding or crumpling occurred during the formation of the Vindhyan boundary fault. There is evidence of such folding, but it appears to be of minor importance.

The tendency in the history of the Indian Peninsula appears to have been that with each successive period of disturbance the amount of folding has decreased and the proportion of change of level due to differential movements has increased. It is not yet sufficiently realised how important normal faulting, with the elevation or sinking of blocks of country, has been in the determination of the relief of the surface of Peninsular India. The faulting of the Gondwana coalfields and the formation of the western coast of the Peninsula by foundering of portions of India now below the ocean, are striking examples of this. Further, recent detailed work in the Central Provinces, especially along the edge of the Deccan Trap formation, has shown us that this part of India has been cut up by a series of post-Deccan Trap faults which have dropped

some blocks and raised others. The great southern scarp of the Gawilgarh hills, north of Ellichpur, which has a downthrow to the south of at least 1,800 feet,[1] giving rise to the plains of Berar is an example of this. The recital of such facts indicates that in the Peninsula extreme caution is necessary in ascribing to any feature great antiquity, and that the period of elevation of Peninsular mountain ranges must, therefore, be discussed separately from the time of folding of the rocks composing the ranges. The two phenomena may or may not be directly related. In ascribing to the Aravalli range an elevation due to rejuvenation by relative uplift along boundary faults, we are, therefore, bringing this orographical feature into its place as a part of the relatively modern period of Peninsular Indian geological history, instead of ascribing this elevation to the more hoary past when mountain ranges were still formed in the Peninsula as a result of folding movements comparable in kind with those by which the Himalayas have been formed in geologically much younger times. The break between the period when fold movements elevated mountain ranges in Peninsular India and the younger periods when block faulting (and tilting) played the predominant part is probably the logically correct period to select as the termination of Archaean times. Our Archæo-Aravalli range was an Archæan range, whilst our rejuvenated Neo-Aravalli range belongs either to the Purana or Dravidian period of Indian geology.[2]

[1] The authority for this figure is Dr. Fox, who, when studying the problem of water supply in Berar, found that the magnitude of this throw was at least 1,800 feet and might be as much as 4,000 feet.

[2] Even our Neo-Aravalli range must be of great antiquity expressed in years. For if we ascribed its rejuvenation to Cambrian times, then, adopting Holmes figures, [*Amer. Jour. Sci.*, XIII, p. 342, (1927)], this re-elevation occurred some 500 million years ago. The amount of denudation that can take place during such a lapse of time explains why it is that even our Neo-Aravalli range is now represented by the wreckage of a mountain range, the height of which even in its highest points above the Vindhyans of Eastern Rajputana and Central India is less than the throw ascribed to the Vindhyan boundary fault that separates them, and which over much of the Aravalli tract has now been eroded to a level less than that of the Vindhyan tract of Eastern Rajputana and Central India.

NOTE ON LAKE'S RULE FOR THE ANGLE OF OVER-THRUST, AS APPLIED TO THE HIMALAYAS. BY L. LEIGH FERMOR, O.B.E., D.SC., A.R.S.M., F.A.S.B., *Officiating Director, Geological Survey of India.*

In a brief paper in the Geological Magazine for 1903, pages 305 and 306, entitled 'The Circular Form of Mountain Chains,' Mr. Philip Lake draws attention to a paper by Professor Sollas [1] in which the author shows clearly that the curve of mountain ranges and of chains of islands often coincides almost exactly with an arc of a circle. Mr. Lake writes:—

'Such a mountain chain is frequently defined along its convex margin by a great reversed fault over which the mountain mass has slid forward; and in these cases, at least, we may safely adopt Suess's conception, and look upon the chain as the crumpled edge of a "scale" of the earth's crust which has been pushed forward over the part in front of it[2]. The surface along which the movement has taken place is called a thrust-plane. If this surface really is a plane, then the edge of the "scale," that is the mountain chain itself, must necessarily be circular in form; for if any plane cuts a sphere, in any position whatever, the outcrop of the plane on the surface of the sphere will always be a circle. There can be no deviation from the circular form unless the "sphere" is not truly spherical, or the "thrust-plane" is not a true plane. On the scale of an ordinary globe the earth is sensibly a sphere, and therefore any deviation which is visible on such a globe must be produced by a deviation of the surface of movement from a true plane.

Further, in the case of a circular mountain range it is possible from the form of the arc to determine the dip of the basal thrust-plane; for it is easy to show that the angle which a plane makes (at its outcrop) with the surface of the sphere is equal to the angular distance, measured on the surface of the sphere, between the centre and the circumference of the circle formed by the outcrop of the plane.

Thus, for example, the centre of the Himalayan arc is placed by Professor Sollas in Lat. 42° N. and Long. 90° E., and the angular distance from this point to the arc is 14°. This, then, is the angle which the basal thrust-plane must make with the surface at its outcrop.

It is not, however, to be expected that the angle thus deduced from the form of the mountain chain will agree with the dip of the boundary fault along its foot; for in a modern mountain chain the actual base will seldom be exposed, and the

[1] 'The Figure of the Earth.' *Quart. Journ. Geol. Soc.*, 1903, p. 180.

[2] The very beautiful sections of the outer Himalayas given by Mr. Middlemiss (*Mem. Geol. Surv. India.*, Vol. xxiv, pt. 2) illustrate the process in operation, and in the North-West Highlands of Scotland we have the actual base of such a mountain chain exposed to view.

faults which are visible at the surface probably bear the same relation to the main thrust-plane that the minor thrusts in the North-West Highlands bear to the major thrust-planes of that region. It is only when the mountain chain has been dissected to its very base that we can hope to see the surface on which the main movement occurred.

If I were to attempt, on this view, an ideal representation of the Himalayas, I should draw, some little distance below Middlemiss's Section VI, a thrust-plane making an angle of 14° with the horizontal.'

In a brief paper published in 1919, Mr. C. S. Middlemiss[1] gives a map on the scale of 2 inches to the mile showing in detail the trace of the thrust-plane between the Murree beds and the Siwalik series in the neighbourhood of Kotli in Jammu; from sections drawn across this map he deduces that at one section (Sarsawah) the angle of this thrust-plane lies between 12° and 15° almost exactly.

In his paper Mr. Middlemiss makes no reference to the paper by Lake, of which he seems to be unaware. It seems desirable, therefore, to direct attention to the remarkable agreement between Lake's prediction, based on theoretical grounds, of the angle of dip that should be assigned to the basal thrust-plane of the Himalayas, and the actual angle of dip determined by Mr. Middlemiss for the main boundary fault of the Himalayas: for this Kotli thrust plane, which, according to Mr. Wadia,[2] terminates in a fold some 14 miles N. W. of Kotli, is the north-western end of the main boundary fault of the Himalayas traceable for some 1,500 miles from Upper Assam nearly to the Jhelum river.[3]

The *raison d'être* of this note is to point out that if the remarkable agreement to which attention has just been drawn be more than fortuitous, as seems likely, we have, in what may be designated Lake's Rule, a powerful weapon for use in considering the structure of overthrust mountain chains.

[1] 'On the Inclination of the Thrust-Plane or Reversed Fault, between the Siwalik and Murree Zone of Formations, near Kotli, Jammu Province'. *Rec. Geol. Surv. Ind.*, Vol. L, pt. 2, p. 122.

[2] *Mem. Geol. Surv. Ind.*, Vol. LI, pt. 2.

[3] The angle of inclination has not been measured elsewhere, but has been assumed to be considerably higher. Mr. Middlemiss, however, in the paper cited, implicitly suggests that these assumptions will prove to require drastic revision when tested by detailed survey.

THE PERMO-CARBONIFEROUS SUCCESSION IN THE WARCHA VALLLEY, WESTERN SALT RANGE, PUNJAB BY F. R. COWPER REED, SC.D. (CANTAB.), *Sedgwick Museum, Cambridge*; G. de P. COTTER, SC.D. (DUB.), *Superintendent, Geological Survey of India*; AND H. M LAHIRI, M.SC. (CALCUTTA), *Sub-Assistant, Geological Survey of India*. (With Plates 10 to 13.)

The three writers of this paper visited in February, 1928, the village and valley of Warcha Mandi in the Salt Range, situated in the Shahpur district, Punjab, (32° 27′; 71° 57′) in order to examine the Permo-Carboniferous sections in that neighbourhood, and make collections of fossils therefrom. The village of Warcha Mandi is well known owing to its salt mine, which has been worked from early Sikh times. An excellent collection of fossils was gathered, the major portion for the Sedgwick Museum, Cambridge. The results of the examination of the Warcha section appear to be of sufficient importance to be placed on record at once in th present paper; the description of the new species amongst the fossil collections will be dealt with at a later date by Dr. Cowper Reed.

The country examined lies immediately to the north and north-east of Warcha Mandi. A small geological map by Mr. Lahiri is attached to this paper, showing the geology, which does not materially differ from the map of A. B. Wynne (Geology of the Salt Range, *Mem. Geol. Surv. Ind.* Vol. XIV), except that it is on a larger scale, and therefore shows greater detail. The geological groups mapped are those of Wynne and are, in descending order.—

1. Ceratite Beds	Permian.
2. Productus Limestone	
3. Speckled Sandstone (including Boulder-bed at base)	Upper Carboniferous.
4. Purple Sandstone[1]	"Purple Sandstone" probably Pre-Cambrian.
5. Salt Marl and Oil Shale undivided	Age unknown.

Wynne's nomenclature has been adopted, except for the Salt Marl, which, in the Warcha section, is associated with an interesting

[1] The term Purple Sandstone has been placed in inverted commas throughout the paper since its correlation with the true Purple Sandstone is disputed. Dr. Reed's views are given in the footnote on page 420, while I and my colleagues Dr. Fox and Mr. E. R. Gee regard the two sandstones as identical. [G. de P. C.]

series of very low grade oil shales with horny siliceous layers. The two have been mapped together by Wynne as the Salt Marl group, but it is probable that they could be mapped separately on a large scale map. It appeared advisable to add the words "and Oil Shale" to the title of group 1—Salt Marl, to indicate the presence of another group intimately associated with the Salt Marl.

From an examination of the map (Plate 13) it will be seen that there are two main stream sections in the country north of Warcha Mandi, (which village is shown on the map under the name of Rukhla, but is generally known as Warcha Mandi or Warcha Market), these two stream sections are (1) that of the main stream which flows south past Rukhla or Warcha Mandi and is known as the Jarhanwala Nala, and (2) that of the Jansukh Nala which falls into the Jarhanwala about 1 mile above Warcha Mandi. Before entering into a detailed description of the sections in these two nalas, it seems advisable to give a brief general description of the exposures.

About one and three-quarter miles above Rukhla, in the main Jarhanwala Nala, the Productus Limestone forms a cliff and waterfall, about 320 feet in height: this cliff is shown in Plate 10, figure 1.

From this cliff southwards, there is an excellent section exposing the lower part of the Productus Limestone. Below this formation the Speckled Sandstone is rather poorly exposed, being frequently covered up by screes; its base and junction with the underlying "Purple Sandstone" however, is well exposed, and the base is distinguished by a boulder bed, which we regard as glacial and the local representative of the Talchirs (Plate 11, figure 2.) Underlying this, are the Purple Sandstones, not so well exposed as in the Jansukh Nala, and these rest upon the upper gypsiferous beds of the Salt Marl group.

The Salt Marl, between this point and Warcha Mandi rises in a gentle dome or anticline, and at the highest point of this dome, which is in the vicinity of the junction of the Jansukh and the Jarhanwala, there are certain shales giving off the characteristic smell of oil shales when heated with a match, and containing horny siliceous layers, slaty beds, etc.[1] This oil shale series appears to underlie the Salt Marl.

[1] A. B. Wynne in his work on the Salt Range (*Mem. Geol. Surv. Ind.* vol. XIV, pp. 231, 232) mentioned the occurrence of these flaggy and shaly beds in the stream section north of the Warcha Salt Mine. No mention is however made of the presence of oil-shale or of the smell of oil in the shales. C. S. Fox (*Rec. Geol. Surv. Ind.* vol. LXI, p. 152) also mentions these shales.

In the Jansukh Nala the "Purple Sandstones" and the Speckled Sandstones above them with their basal (Talchir) conglomerate and boulder bed are well exposed, but the section through the Productus Limestone is not so good as that of the Jarhanwala Nala. By combining the observations from both sections, a very good idea of the whole succession can be obtained.

In the hills between the two nalas, the Productus Limestone yielded abundant fossils. On the hill-slopes, the fossils weather out beautifully and can be gathered from the ground. In the stream sections the fossils have to be chipped from the rock. Hence most of our collections were obtained from the high ground between the two streams and from the heights above the Jarhanwala to the west. We were able to correlate our fossil collections with definite horizons in one or other of the stream sections, through the occurrence of some characteristic beds on the hill-side, one bed especially,—an annelid limestone (pipe-rock) with a capping of conglomerate,—was found to constitute a very useful datum-line.

We may now describe the various formations in detail.

The Oil Shale Group.

The most southerly exposure of the oil shale group is just south of the Jansukh and the Jarhanwala, but the exposures continue north of the junction up the Jarhanwala for over a furlong, and for a somewhat shorter distance up the Jansukh. They are a series of low grade oil shales containing cherty siliceous layers, and interbedded green sandy clays, with occasional carbonaceous markings, but no definite trace of either plant or animal fossils, and showing rather vivid colours in greys, greens and chocolates. The structure of the oil shale rock is cryptocrystalline, but there are a few scattered grains of quartz visible; under the microscope it shows a blackish staining due most probably to ferruginous material. There is no effervescence with acid. The rock smells feebly of oil when heated with a match, but does not ignite or smoulder. It is not resilient under the hammer, nor can it be cut with a knife without crumbling. It is apparently a very low grade oil shale, and cannot be regarded as of any commercial value.

Wherever this series is exposed, the dip is generally steep, and the beds are crumpled and folded into miniature anticlines and synclines, and in one or two sections the group appears to be actually interbedded with the Salt Marl; this appearance however is possibly deceptive, and the sections are perhaps to be explained as narrow

broken anticlines. Usually the contact with the Salt Marl suggests shearing, and the latter has in certain places a brecciated structure with fragments apparently derived from the Oil Shale group. A photograph of one of the folded oil shale anticlines is shown in Plate 11, figure 1. The Salt Marl, which is gently folded and comparatively little disturbed (except for some autochthonous wedges of Purple Sandstone with overthrust Salt Marl) in the neighbourhood of Warcha Mandi (- Rukhla) shows considerable disturbance at its junction with the Oil Shale series and partakes in the folding into miniature anticlines and synclines seen in the Oil Shales. We consider it possible that the Oil Shales may be stratigraphically separable from the Salt Marl, but no definite conclusions can be drawn from the study of one section only.

All other occurrences of oil and bitumen in the Punjab outside this Salt Range area are Tertiary in age. On this and on other grounds Sir Edwin Pascoe has argued the Tertiary age of the Salt Marl (*Mem. Geol. Surv. Ind.* XL, p. 364). Our work has not thrown any fresh light upon this question; the oil shales and bituminous rocks of the Salt Range may indeed be Tertiary, although there is nothing intrinsically absurd in supposing them to be Pre-Cambrian; on the other hand the relationship of the oil shales to the Salt Marl is not sufficiently clear. They appear to underlie the Salt Marl, but, as noted above, the junction is disturbed and brecciated, and the sequence may not necessarily be a normal one; the possibility that the position of the Salt Marls overlying the Oil Shales may be due to overthrusting should be kept in view, and decided by future work.

Mr. Lahiri measured a good exposure of the Oil Shale series in the Jansukh Nala near its junction with the Jarhanwala and obtained the following :—

Descending Order :—	Feet.
Salt Marls	
Green marls with gypsiferous bands	15
Oil shales with horny siliceous layers	36

The Salt Marl.

The Salt Marl was not examined in detail. It has been pointed out that it shows little disturbance near Rukhla, but contains wedges of "Purple Sandstone," dipping gently, with Salt Marl above and below. This proves the existence of thrust-planes in the Salt Marl. In the neighbourhood of its junction with the Oil Shale series it is crumpled and disturbed.

It contains gypsum in abundance near its contact with the "Purple Sandstones" above. The salt-bearing beds at Rukhla lie below the gypsiferous zone.

The "Purple Sandstones."

The best section of the "Purple Sandstones" is that of the Jansukh Nala. Here the total thickness is 260 feet as follows :—

Descending Order :—	Feet.
Harder, paler. and more massive sandstones	90
Well bedded earthy purple sandstones	170

The upper surface of the paler purple sandstone in the Jansukh section shows ripple marks, and is covered by a thin boulder bed consisting of boulders of varying size in a sandy matrix. This is the basal bed of the Speckled Sandstone. There is no trace of slickensiding nor of any movement at the junction of the boulder bed and this "Purple Sandstone"; the boulder bed is strongly adherent to the latter, and could not possibly have been brought into its present position by thrusting; it follows therefore that, since the boulder bed is, as will be afterwards shown, of Talchir age, the age of the underlying "Purple Sandstones" is unquestionably Pre-Talchir. (*See* footnote on page 420.)

In the Jarhanwala Nala, the section through the "Purple Sandstone" is as follows :—

Descending Order :—	
Boulder bed at base of Speckled Sandstone.	Feet.
Massive, well bedded and well jointed fine grained banded greenish grey to light purple sandstones	93
Shattered Purple Sandstones badly exposed	12

The contact of the "Purple Sandstones" and the Salt Marl is here badly exposed, but a thrust is suggested by the shattered conditions of the basal sandstones, and by the fact that whereas 170 feet of this basal division of the "Purple Sandstones" are exposed in the Jansukh Nala, only 12 feet are seen in the Jarhanwala. The missing beds and the shattered condition of those left strongly suggest a thrust. The 93 feet of light purple sandstone above corresponds very well with the upper division of the "Purple Sandstones" in the Jansukh section which is 90 feet thick.

In the Jansukh Nala, it appeared from an examination of a cliff section, that there was some slight overriding of the Speckled Sandstones over the "Purple Sandstones," the movement probably taking place in the soft sandy basal beds of the Speckled Sandstones,

but without disturbing the boulder bed. This overriding is very strongly developed on the high ground between the Jansukh and the Jarhanwala. Here the "Purple Sandstone" is completely cut out by *chevauchement*, and some of the lower beds of the Speckled Sandstone are also missing.

The Speckled Sandstone, I. Talchir Boulder Bed.

The basal boulder bed of the Speckled Sandstone in the Jansukh Nala varied in thickness from 6 inches to 2 feet. It consisted of boulders of varying size, the largest seen being 2 feet long and 1 ft. 4 inches in width. Some of the boulders are flattened on one side as might be expected in a glacial deposit, and many are polished, but no scratches were seen. The surfaces of the boulders are often pitted. They are set in a coarse pepper and salt sandy matrix, the whole being strongly adherent to the "Purple Sandstone." A photograph of the boulder bed in the Jansukh Nala is shown in Plate 10, figure 2. In the Jarhanwala Nala, on both sides of the stream the basal bed of the Speckled Sandstone contains scattered boulders, which rest upon the top bed of the "Purple Sandstone." There is here no definite differentiated boulder bed and a more correct idea of the section is obtained if we regard the Speckled Sandstones as containing scattered boulders at the base. In both of the exposures of the Boulder-bed, the evidence suggests that the erratics have been dropped by floating ice, and the bed has none of the characteristics of a typical tillite. A photograph of the section in the Jarhanwala showing the boulders is seen in Plate 10, figure 2.

Our colleague Mr. A. L. Coulson has kindly examined microscopically the boulders collected from this bed. The rock specimens may be divided into two groups, (1) graphic granites. and (2) rhyolites and porphyries. Below is Mr. Coulson's account of these rocks. He says—

"The boulders from the Salt Range are chiefly granites, most of which are very similar to one another. In the hand specimens, they show abundant pink orthoclase and colourless quartz, with, at times, a peculiar greenish tinge due to the decomposition of the ferro-magnesian mineral or minerals present.

In thin section the most abundant mineral is seen to be orthoclase, generally, but not always, untwinned, and almost invariably slightly kaolinised; plagioclase is also present, but to a far lesser extent. Quartz is plentiful; it is generally free from strain-polarisation between crossed nicols, but shows numerous minute inclusions.

Apart from chlorite, to which it is more or less completely altered, biotite is the only ferro-magnesian mineral present in the six sections which were examined. Iron ore is accessory but not to any great extent.

The most characteristic feature of this granite suite is the occurrence of micrographic intergrowths of quartz and orthoclase. These are to be found in greater or less amount in all the sections except one, in which last nearly all the quartz and orthoclase appear to have crystallised out in eutectic proportions.

Some specimens are very fine grained, showing an intergrowth of quartz and orthoclase with a little plagioclase and biotite. As mentioned above the intergrowth of the two first minerals is at times graphic,

C. S. Middlemiss (*Rec. Geol. Surv. Ind.* XXV, p. 34) has described a rock (no. 8/473 from the boulder bed of the Salt Range which, according to La Touche (*Mem. Geol. Surv. Ind.* XXXV, p. 87) very closely corresponds with some of the rhyolites of Western Rajputana. La Touche (*op. cit.* p. 90) also notes the similarity of a granite from the north east slope of Chel Hill, Salt Range, collected by Middlemiss, (*op. cit.* pp. 33, 34) to the Siwana granite of Western Rajputana. The characteristic feature of this granite as seen in thin section (slide 655) is the development of a beautiful micro-pegmatitic structure.

La Touche notes the presence of hornblende in the Siwana granite. In the specimens collected by Dr. Reed and Dr. Cotter no hornblende was noticed, the ferro-magnesian mineral being biotite. The granite boulders under examination thus resemble La Touche's Jalor granite, (*op. cit.* p. 91) though there is not "a fair proportion of plagioclase." Apart from the presence of hornblende, the section (no. 655) of Middlemiss' rock (8/472) shows a remarkable resemblance to one of the specimens in the present collection (no. 37/719A).

The granite specimens under consideration are not very dissimilar to a specimen of Jalor granite (11/709) collected by La Touche from a spur south east of Kundal in Western Rajputana; but they more closely resemble specimens of granite from near Waloria (Long. 73°, 4′; Lat. 24°, 39′) which are registered under the numbers 34/246, 34/247, 34/249. Another closely similar granite is found near Danta (Long. 72°, 51′; Lat. 24°, 48′ 30″) registered number 36/83. These localities are in Sirohi State, Rajputana, and both these granites have been tentatively referred to the Jalor Granite of La Touche. The resemblance is not so great in thin section, as there is a general absence of graphic structure in the Waloria specimens, although graphic structure does occur in other specimens from Danta and Isri (See *Rec. Geol. Surv. Ind.* LX, p. 115)."

To the above valuable note of Mr. Coulson, we may add that pink granites of a somewhat similar type are described by McMahon from Tusham hill and neighbourhood (*Rec. Geol. Surv. Ind.* XVII, p. 111) Tusham Hill is 85 miles west by north of Delhi in Long. 76°, Lat. 28°, 50′.

The second group of rocks found in these boulders are porphyries and rhyolites, and of the three sections prepared, one probably a rhyolite, shows a beautiful banded structure. Mr. Coulson gives the following description :—

"The rock shows a definite banded structure, with bands of finely crystalline quartz and orthoclase with a certain amount of what may be residual glass. These

bands are separated by more or less continuous stringers of quartz which appear to show a phase of secondary crystallisation. These quartz bands curve round idiomorphic crystals of orthoclase which are set in the finely crystalline ground mass. Radial growths of felspar are found with some of the quartz ; these would also appear to be secondary in nature as distinct from the primary nature of the phenocrysts. The other two microscope slides are somewhat similar to the above section, except that there is an absence of any banded structure. These sections chiefly show hypidiomorphic phenocrysts of felspar in a finely crystalline ground mass of quartz and felspar, together with abundant chlorite. The chlorite gives a greenish colour to the hand specimens. These two last specimens are probably hypabyssal."

Mr. Coulson has refrained from comparing these rocks with the Malani suite of rhyolites and associated hypabyssals (porphyries), but the resemblance of the rhyolitic Salt Range boulders to the Malani suite has been noticed by Middlemiss (*op. cit.* p. 35), by La Touche (*op. cit.* p. 87) and lastly by A. M. Heron (*Rec. Geol. Surv. Ind.* XLIII, p. 233), Dr. Heron remarks in his survey of the Kirana Hills, which lie to the south east of the Salt Range and are the nearest exposures of the older rocks to the Salt Range, that he examined Middlemiss' collection of specimens from the boulder bed of the Salt Range, and he says—

"The majority of these are in no way similar to the Kirana rocks, but in a few cases noted below the resemblance, though not amounting to identity, is enough to show that some of the rocks of the boulder bed were in all probability derived from the area under consideration.

Boulder Bed.	Kirana.
8/473 (slide 686) . . .	23/32 (slide 7587) 23/30 (slide 7587) devitrified rhyolites with quartz and feslspar phenocrysts.
8/480 (slide 663) . . .	23/34 (slide 7589) 23/26 (slide 7581) coarse grain tuffs (?) "

The above description confirms the view expressed by Middlemiss that the Salt Range boulders were derived from the south and not from the north. The resemblance to the Rajputana granites and to the Malani suite is too close to be accidental.

Before proceeding to a description of the beds above the boulder bed, attention may be drawn to the fact that the Boulder Bed rests upon the "Purple Sandstone," and thus definitely proves that the "Purple Sandstone" of the Warcha section is Pre-Talchir. With this may be coupled the observations of Messrs. Oldham and Middlemiss (*Rec. Geol. Surv. Ind.* XXIV, pp. 21, 22) that amongst their collections of striated and facetted rocks from Khusak (Eastern

Salt Range) was a scratched boulder of Purple Sandstone. In the last paper quoted the stratigraphical relationships of the Boulder Bed are discussed. It is stated to rest to the east on the Salt Pseudomorph zone, but west of Makrach it is said to overstep the Salt Pseudomorph zone and to become directly superposed upon the Magnesian Sandstone. Middlemiss notes that in the Amb glen (which is about 5 miles N. of Warcha) and neighbourhood, the Boulder Bed, "which still forms the base of the Speckled Sandstone, is in contact sometimes with the Purple Sandstone and sometimes with the Red Marl." From a perusal of Middlemiss' paper, it will be seen that the Salt Range is an area of repeated thrust faults, and the position of the Boulder Bed is frequently abnormal, although its true stratigraphical position at the base of the Speckled Sandstone is certain.

Our observation that the Boulder Bed rests upon the "Purple Sandstone" is confirmatory of the work of Oldham and Middlemiss, whatever opinion be held as to the age of this sandstone.[1]

[1]The correlation of these "Purple Sandstones" near Warcha with the typical Purple Sandstone of the type sections near Khewra in the Eastern Salt Range where the Sandstone directly underlies the Neobolus Shale Group is usually considered to have been established by the work of Middlemiss and others. The Cambrian beds are stated to thin out successively when traced from East to West, and the boulder bed which varies much in thickness (being as much as 150 ft. in some sections) is said to overlap unconformably the members of the Cambrian series till it comes to rest directly on the Purple Sandstone in the Kattha area as well as at Warcha and at Amb further west. Taking the exposures in the Jansukh Nala and Jarhanwala Nala alone there is nothing to suggest a break in the succession, much less an important stratigraphical gap, and Mr. E. R. Gee states that similarly in the Kattha area "one would not suspect a stratigraphical break between the two deposits." Not only is there no apparent interruption in the sequence or any unconformity but the dip and strike of the two deposits as seen in the Jarhanwala Nala and Jansukh Nala seem to be identical (see Plate 11, figure 2), and from these sections one would be led to conclude that there had been continuous sedimentation. Moreover, no marked difference in the lithological character and physical condition of the underlying sandstones and of the rock containing the boulders is noticeable, and a close connection in age might be reasonably suspected, and the sandstones be held to represent the lower part of the elsewhere thick boulder-bed which is here reduced to 6 inches up to 2 feet. Without venturing to question the observations of other workers in this area owing to my limited personal acquaintance with the geology of the Salt Range it has seemed desirable to place on record a possible interpretation of the particular sections which have come under my notice, as many problems of this district are yet unsolved or are in dispute.

F. R. C. R.

I prefer to regard the "Purple Sandstone" of the Warcha Glen as identical with that underlying the Neobolus Beds to the east. I regard it as Pre-Cambrian in age, and assume the existence at Warcha of a great stratigraphical gap below the Talchir Boulder-bed.

G. de P. C.

In the Jansukh Nala, the following beds are exposed above the thin basal boulder bed :—

Speckled Sandstone II. Upper Division.

Descending order :—	Feet.
1. Fusulina limestone, which is part of the Productus Limestone and is not to be grouped with the Speckled Sandstone. (K. 24·620.)	
2. Finely laminated carbonaceous sandstone	27
3. Lavender Clays, see Wynne (*Mem. Geol. Surv. Ind.* XIV, p. 90)	42
4. Purple and white sandstones with thin strings of pebbles, easily distinguished from the Purple Sandstones by the softer grain and coarser character	277
5. Fine grained green sandstones with coaly laminae and much concretionary iron stains and a few indistinct plant remains	38
6. Boulder Bed	6 inches to 2 ft.

This gives a total thickness of 384 feet for the Speckled Sandstone. The junction of beds 3 and 4 was obscured by screes, but we regard the whole sequence from the Boulder Bed upwards to the Productus Limestone as conformable. It is a matter for regret that we were unable to find any fossils in the Speckled Sandstones at Warcha. In the hilly ground between the Jansukh and Jarhanwala Nalas, some of the basal beds of the Speckled Sandstone are cut out by thrusting, but they are again visible in the Jarhanwala, although the section here is not so good as that of the Jansukh. In the Jarhanwala[1], we obtained the following section :—

Descending order :—	
Bed 1. Beds ill seen, passing upwards into carbonaceous laminated shale with ochre and small crystals of decomposed pyrites and of gypsum, dipping at 31 degrees to 26° E. of N.	Thickness 156 feet.
Bed 2. Calcareous Marl	Thickness 7 feet.
The beds here curve across the stream from east to west in an anticlinal nose.	
Bed 3. (=3 Jansukh) Lavender Clays with white bands, base ill seen	More than 45 feet.
Bed 4. (=4 Jansukh) Coarse soft purple sandstones and grits with bands of small sub-angular pebbles, top concealed by screes	More than 50 feet thick.
Bed 5 (=5 and 6 Jansukh) Dark green sandstones and shales with carbonaceous laminae and glaciated boulders at base	More than 32 feet (upper beds ill seen).

[1]The beds are seen on both sides of the stream, but the section is clearer on the left bank.

Above this come Fusulina beds crowded with specimens of *Fusulina*, which we include in the Productus Limestone. Here again we appear to have a conformable sequence.

The change from a sandstone and shale facies to a calcareous one is not sharp; it will be seen that there are several arenaceous beds and marl and shale horizons near the base of the Productus Limestone.

Sections through the Productus Limestone.

The section through the Productus Limestone in the Jarhanwala Nala was carefully studied. Here the lower Productus Limestone is well exposed. The middle beds are seen in vertical cliff section at the waterfall (Plate 10, figure 1) where the stream descends over a vertical cliff about 320 feet in height. A portion of the upper Productus Limestone extends to the beds above the waterfall.

The following are our measurements :—

	Feet.
Descending Order :—	
1. Massive thick bedded cream and white limestones forming the main cliff of the waterfall ("Cliff Limestones"). Estimated thickness	203·0
2. Alternate thin bands (1½ ft. to 6 inches thick) of grey limestone, alternating with thinner bands of grey shale, with very few fossils, (*Spirigerella* near base). (K. 24·595.) These form the lower portion of the face of the waterfall. The thickness, estimated with Abney Level by rough triangulation is	73·0
3. Sandy limestone with iron band near top, containing *Hustedia*, *Spirifer fasciger*, *Athyris*. etc. (K. 24·594) . . .	11·0
4. Grey shales, carbonaceous at base, ill seen	28·0
5. Impure arenaceous annelid limestone, ("pipe-rock") with a capping of calcareous conglomerate above, containing iron-stone pebbles, and green shattered shale in the calcareous matrix. *Polypora* and *Spirifer fasciger* present. (K. 24·593)	1·8
6. Carbonaceous shales, sandy near top, with fossil plants, *Gangamopteris*, *Glossopteris*, etc. (K. 24·592) . . .	22·0
7. Soft beds, apparently limestone, ill seen	26·0
8. Massive unfossiliferous limestone. There is a hard carbonaceous band 2 feet from top. Fragments of *Bellerophon* on top	8·1
9. Sandy limestone with carbonaceous bands	1·8
10. Massive unfossiliferous carbonaceous limestone	14·0
11. Shell marls with abundant bryozoa (*Geinitzella*, *Polypora*) and numerous badly preserved brachiopoda (*Spirifer fasciger*), *Strophalosia* spines, etc. These marls pass upwards into carbonaceous shales. (K. 24·591)	8·0
12. Grey slightly carbonaceous shales with fragmentary fossils (*Spirifer*, etc.) at base	2·0

	Feet.
13. Massive Limestone, weathering with a pitted surface, containing *Spirifer fasciger, Martinia*, etc. (K 24·608) . . .	3·9
14. Carbonaceous shale with ochre	1·4
15. Limestone with broken shells, (*Strophalosia*, etc.) (K 24·590) .	1·0
16. Fusulina Limestone with small brachiopods near top, containing *Spirifer, Athyris, Derbya* (K 24·589)	4·0
17. Shattered horny limestone	1·2
18. Fusulina Limestone crowded with *F. kattaensis* with narrow bands or lenticles full of brachipod shells, (K. 24·587·588) .	13·4
19. Black and drab shales with traces of plant remains ; one *Marginifera* collected	26·0
20. Shelly Limestone with poorly preserved fossils, *Spirifer, Athyris, Strophalosia*, and *Chonetes*, (K 24·586) . . .	0·7
21. Carbonaceous marls with unidentifiable plant remains, apparently of a small leaved fern or seed-fern	3·0
22. Shell Marls with *Marginifera, Hustedia*, etc., fossiliferous near base, and with a 4″ band of sandstone near top (K. 24·585) .	14·0
23. Slightly carbonaceous marls with very few fossils and flat nodules of buff limestone at base. (K. 24·584) . .	6·0
24. Very coarse calcareous sandstone with rounded quartz pebbles and containing lenticles of a finer grained sandstone, almost unfossiliferous. (K. 24·578)	2·6
25. Greenish arenaceous limestone with minute fragments of broken shells	1·0
26. Fusulina Limestone with a few crinoid stems and very few obscure brachiopods. (K. 24·576)	7·7
27. Calcareous laminated shale with ochre and small crystals of decomposed pyrites and of, gypsum (dipping at 31° to 26° E. of N. and 4·4 feet in thickness), followed by calcareous sandstone, mainly unfossiliferous, but with a few *Fusulinae* at base (11·8 feet in thickness K. 24·575), total thickness . .	16·2

The above section gives a total thickness of 501·7 feet of which the lower 225·7 feet can be broken up lithologically into small units owing to the alternation from limestone to shale and sandstone and even conglomerate and plant-bearing carbonaceous shales ; the upper 276 feet are much more homogeneous, and cannot be subdivided in the same manner as the lower section. The lower 225 feet are characterised by abundant *Fusulina* in their lower portion, and by fresh water beds with plant remains in the upper part. The fauna of the marine bands appears to be uniform in character, but the fossils in these beds are mostly poorly preserved and difficult to extract. The most abundant and conspicuous species is *Spirifer fasciger* var. *musakhelensis*. The upper 276 feet are entirely marine. It will therefore be seen that the change from the arenaceous facies and land or fresh water and shallow marine conditions which characterise the Speckled Sandstone to the definite marine conditions of the middle and upper Productus Limestone is a very gradual one ;

the alteration in facies is nowhere sudden, and there is no evidence of any unconformity or of any stratigraphical gap. Bed 5 is especially interesting as being an example of a "Pipe-rock" such as has been described by Holtedahl from the Upper Carboniferous of Bear Island (*Norsk Geol. Tidskrift:* Bd. VIII, heft 4, p. 270) and by Richter from the Devonian of the Eifel (*Senckenbergiana*, Bd. II, heft 6, pp. 215-235). The pipes are vertically disposed and are about a quarter of an inch in diameter, and set at distances averaging about an inch from one another.

Sections in Hilly Ground between the Jarhanwala and Jansukh Nalas.

There are two paths leading up the hilly ground between the Jansukh and the Jarhanwala Nalas. The first leaves the Jarhanwala just beyond its junction with the Jansukh, and is maintained as a bridle path by the Salt Department. The other path leaves the Jarhanwala about a quarter of a mile below the waterfall, and meets the bridle path near a hut marked on the map as Kumaranwali. Kumaranwali is not a village, but what is known as a *dhok* or farmer's hut, and there are two huts, one of which is in ruins, and the other in good repair and inhabited. The ruined one is some 100 feet or so below the inhabited *dhok*.

There are two small wheat fields at the ruined *dhok*, and here on the south side of the wheat fields, the annelid limestone (K. 24·599) with its calcareous conglomerate cap (K. 24·596) (Bed No. 5 of the Jarhanwala section) can be recognised. Below the annelid limestone, the *Gangamopteris* bed of the Jarhanwala (No. 6) is represented by sandstones and shales with carbonaceous laminae. There is no trace of plant remains, but the horizon here contains large *Serpulites*, etc. (K. 24·579). At a lower horizon, along the bridle path which leads from the ruined *dhok* to the junction of the Jarhanwala and Jansukh, there is an exposure of Fusulina Limestone (K. 24·600), containing *Spirifer* and *Productus*. We could not correlate this with any bed in the Jarhanwala section, but perhaps it may correspond with bed 7, which was covered by screes in that section.

On the footpath which leads from the waterfall to the *dhok*, at the first dip slope, which forms a kind of terrace half way up the path, we obtained a very large collection, mainly of small brachiopods, but with several specimens of bryozoa and corals and not a few gasteropods, especially *Bellerophon* and *Euphemus* (K. 24·580). When climbing up the path to the *dhok*, it appeared to us that we were approximately on the same horizon for some considerable

distance, since the rocks are folded into a sharp anticlinal dome, which appears to nose out under the "cliff limestone" (No. 1 of Jarhanwala). It is probable then that these highly fossiliferous beds found on the path are to be correlated with division 4 of the Jarhanwala section.

The remaining exposures to be considered are (1) those between the ruined and the inhabited *dhok*, and (2) those above the inhabited *dhok*. On the slopes between the two *dhoks*, a good collection was obtained (K 24·581). This horizon was rich in specimens of *Bellerophon* and allied genera.

Above the inhabited *dhok*, follows a considerable thickness, perhaps 100 feet or so, of arenaceous limestones (K 24·582). characterised by abundant *Bellerophon*. These beds correspond with part of the "cliff limestone" (No. 1).

Climbing upwards in direct ascent, we again came upon the bridle path, which winds in zigzag fashion up hill. Here above the *Bellerophon* zone, are exposed somewhat sandy limestones (K 24·583), characterised by abundant *Productus abichi*, and by *Derbya grandis*. These beds lie stratigraphically immediately above the "cliff limestone" (No. 1). Above the *Productus abichi* zone, comes a great thickness of very well bedded very homogeneous very sandy limestones. Owing to crumpling and to the abundant screes which conceal actual exposures, we could not estimate the thickness accurately, but it appears to be roughly about three hundred feet, giving a total thickness of about 800 feet for the Productus Limestone and Lower Trias. As the Lower Trias is here about 100 feet thick, this gives a thickness of 700 feet approximately for the Productus Limestone.

About two-thirds of the way up the slope, where these upper three hundred feet of strata are exposed, is a *Bellerophon* bed, which we named the "upper Bellerophon bed" (K 24·601), as distinct from the *Bellerophon* bed just above the inhabited *dhok* mentioned below.

The topmost 100 feet of this exposure, that is to say the beds above the upper *Bellerophon* bed are full of Lower Trias cephalopods (*Pseudosageceras*, *Meekoceras*, *Aspidites*, *Flemingites*, *Ophiceras*, *etc.*) and of little else. These topmost beds are flaggy and of a fine grain.

The bridle path, which leads to a village called Uchhali, here crosses a dividing ridge, and commences to descend into the valley of the Jarhanwala above the waterfall. Here on the divide is

exposed the upper Bellerophon bed, (K 24·597), from which a new nautiloid was collected, and the cephalopod limestone occurs above. To the north a lofty cliff of limestone is seen; this limestone (K 24·602), contained *Lyttonia*, *Lonsdaleia* and *Spirifer*, and there was a complete absence of cephalopods. It appears clear that it is the "cliff limestone" (No. 1) repeated possibly by overthrusting over the cephalopod limestone. In the upper Jarhanwala, between this "cliff limestone" and that of the waterfall, the Speckled Sandstone is exposed, and the repetition is quite clear. We had not time to visit the stream section. A panoramic photograph was taken, (Plate 12), which strongly suggests an overthrust structure, and shows the two cliffs of "cliff limestone."

Section along road from Rukhla to Amb.

The road from Rukhla to Amb begins from near the bottom of the Warcha glen below the Salt mines and ascends a steep slope first through the Salt Marl and thereafter through the Productus Limestones (K 24·603, 604). These are full of *Productus abichi*, and correspond with those on the opposite side of the valley. The Productus Limestone which in this section directly overlies some purple clays, is first met with along the road at a height of 480 ft. (by aneroid) from the bottom of the glen. The purple clays underlying the limestones probably belong to Wynne's "Lavender Clays" or the uppermost member of the Speckled Sandstone group. Some subordinate sandy shales and carbonaceous bands are included in the limestones near the base. Further above, the road follows a more or less level course till where it forks and sends out a side-track towards Daryunwali *dhok*. The road in this portion passes through compact cream or white limestones (K 24·605) with occasional intercalations of sandy beds. The cliff seen to the west of the road midway between Rukhla and Fazalwali *dhok* consists entirely of the creamy compact limestone. Fossils collected from the limestones at the base of the cliff and from the sandy bed on the top of the cliff include among others *Productus lineatus*, *P. indicus*, *Chonetella nasuta*, crinoid stems, etc. (K 24·606 and 607). North of the fork, the road ascends towards Fazalwali *dhok*. The compact creamy or white limestone continues over this portion of the road also. Amongst the fossils collected from the hill-slopes above Fazalwali *dhok*, is a coral of *Lonsdaleia* type.

Judging from its fossil contents and from its cliff-forming nature, the compact limestone in this section seems to correspond to the

"Cliff Limestone" or Bed No. 1 of the Waterfall section. The lower part of the Productus Limestone on these hill-slopes with the carbonaceous beds near the base would probably correspond to Beds 4 to 2 of the Waterfall section. The Lower Productus Limestone beds are entirely absent in this section, the characteristic Fusulina-bed or the Annelid sandstone having nowhere been met with.

Distribution and lists of the fossils. (F. R. C. Reed).

The chief localities from which fossils were collected comprise the following :—(1) the waterfall section at the head of the Jarhanwala nala ; (2) the hillsides on the south side of the valley in the neighbourhood of the Kumaranwali dhoks ; and (3) the road from Rukhla towards Amb on the north side of the valley.

With the exception of the topmost beds on the way to Uchali (K 24·598) which are Lower Triassic having yielded typical ammonoids, all the beds contain fossils which indicate a Permo-Carboniferous age, and a large number of the species described by Waagen are represented. A few new species will be described in a subsequent paper with critical notes on some of the other forms. The whole series of the Productus Limestones appears to be present. In the Waterfall section the beds below the Annelid limestone (pipe-rock) (K 24·593) may be referred to the Lower division and are characterised by *Fusulina* ; the beds above, including those on the slopes up to the Kumaranwali dhoks, may be placed in the Middle division, and from the abundance of the species *Productus abichi*, *P. tumidus*, *P. compressus* and *P. gratiosus* we may refer the *P. abichi* beds to the same division on the strength of Waagen's list (Salt Range Foss. I, pt. 2, p. 672) which gives the distribution of the species of this genus, though the abundance of *Bellerophon* and *Euphemus* in the Lower Bellerophon bed (K 24·582) would suggest, according to that author, the Upper division. The Upper Bellerophon Bed may, however, be definitely ascribed to the Upper division, as it immediately underlies the Ceratite beds of Lower Triassic age (K 24·598).

On the opposite side of the valley on the road from Rukhla to Amb the whole series of beds (K 24·603-607) contain a fauna which points to the Middle division of the Productus Limestones.

The identification of the species in this collection from the Warcha district has been much facilitated by the examination of the types and other specimens from the Salt Range and Himalayas in the Calcutta Museum.

List of fossils collected from the Productus Limestones.

(1) Waterfall section at head of valley of Jarhanwala nala, Warcha.

Bed 27. (K 24·575)

Fusulina kattaensis Schwager.
Cyathocrinus sp.
Orthis (*Schizophoria*) *indica* Waag.
Strophalosia sp.
Polypora sp.

Bed 26. (K 24·576)

Fusulina kattaensis Schwager.
„ *longissima* Möll.
Athyris acutomarginalis Waag.
Productus (*Marginifera*) *transversus* Waag.
Orthis cf. *pecosi* Marcou.

Bed 24. (K 24·578)

Derbya grandis Waag.
Spirifer (*Neospirifer*) *fasciger* Keys. var.

Bed 23. (K 24·584) *Orthis* (*Schizophoria*) cf. *indica* Waag.

Bed 22. (K 24·585)

Spirigerella derbyi Waag.
Productus (*Marginifera*) sp.
Hustedia grandicosta Dav. ?

Bed 20. (K 24·586)

Chonetes ambiensis Waag.
Strophalosia tenuispina Waag.
„ *plicosa* Waag.
Aulosteges sp.
Spirigerella sp.
Athyris semiconcava Waag.
Martinia sp.

Bed 18. (K 24·587)

Fusulina kattaensis Schwag. (from screes).
Geinitzella sp. (from screes).

Bed 12. (K 24·588)
Spirifer sp.
Athyris sp.
Derbya sp.
Liebea salinaria sp. nov.

Bed 14. (K 24·589)
Spirifer marcoui Waag.
Athyris subexpansa Waag.
Derbya ? sp.

Bed 13. (K 24·590)
Strophalosia sp.
Spirifer sp.

Bed 11. (K 24·608)
Spirifer (*Neospirifer*) *fasciger* Keys.
Martinia semiplana Waag. *radiata* var. nov.
Spirigerella sp.
Strophalosia sp.
Geinitzella sp.
Polypora sp.

Bed 9. (K 24·591)
Spirifer (*Neospirifer*) *fasciger* Keys.
Athyris capillata Waag.
Aulosteges medlicottianus Waag ?
Polypora sykesi De Kon. ?
Domopora ? *ambigua* sp. nov.
Polypora sp.
Stenopora ovata Lonsd.
Spirorbis helix King.
Helodopsis ? sp.

Bed 5. (K 24·593)
Spirifer (*Neospirifer*) *fasciger* Keys.
Chonetes strophomenoides Waag. ?
Athyris ? sp.
Strophalosia ? sp.
Polypora sp.
Hexagonella ? sp.

Bed 3. (K 24·594)
Spirifer fasciger Keys.
Athyris semiconcava Waag.

Bed 2. (K 24·595)
Spirigerella derbyi Waag.
Martinia elegans Dien. *particeps.* var. nov.
Polypora sp.

(2) South side of valley of Jarhanwala nala.
Path from Waterfall to Kumaranwali dhok (K 24·577).
Lonsduleia indica Waag. and Wentz.
,, *virgalensis* Waag. and Wentz.
Arœopora ramosa Waag. and Wentz.
Crinoid stems.
Productus (*Linoproductus*) *lineatus* Waag.
,, (*Productus*) *indicus* Waag.
,, (,,) *subcostatus* Waag.
,, (,,) *gratiosus* Waag.
,, (*Waagenoconcha*) *abichi* Waag. *consors.* var. nov.
,, (,,) *purdoni* Dav.
,, (,,) *fugax* sp. nov.
,, (*Marginifera*) *typicus* Waag.
Chonetes (*Dienerella* sp. nov.) *grandicosta* Waag.
,, *squama* Waag.
Chonetella nasuta Waag.
Strophalosia rarispina Waag.
,, *excavata* Gein.
Terebratuloidea depressa Waag.
Notothyris inflata Waag.
Hustedia grandicosta (Dav.).
Spirigerella derbyi Waag.
,, ,, var. *acutiplicata* Waag
,, *grandis* Waag.
,, *praelonga* Waag.
Athyris globulina Waag.
,, *subexpansa* Waag. ?
,, *pectinifera* Sow.
,, *simulans* sp. nov.
Spiriferina cristata Schloth.

Spirifer (Neospirifer) fasciger Keys.
Camarophoria nucula Schellw. *saxatilis.* var. nov.
Streptorhynchus cf. *pelargonatus* Schloth.
,, *(Kiangsiella) pectiniformis* Dav.
Richthofenia lawrenciana De Kon.
Cardinocrania indica Waag.
Polypora megastoma De Kon.
,, *ornata* Waag. and Pichl.
,, *gigantea* Waag. and Pichl.
Fistulipora parasitica Waag. and Wentz.
Bellerophon jonesianus De Kon.
,, *affinis* Waag.
,, *triangularis* Waag ?
,, cf. *vigili* Stache.
Stachella semiaurita Waag. ?
Bucania integra Waag.
Euphemus indicus Waag.
,, *apertus* Waag.
Entalis herculea De Kon.
Pleurotomaria ? sp.
Orthoceras sp.

Near Kumaranwali dhok (K 24·600).
Fusulina pailensis Schw.
Spirifer oldhamianus Waag.
,, *vercherei* De Vern.
Productus sp.
Strophalosia sp.

Sandy greenish limestone (=Annelid limestone, bed 5 of Waterfall section) near Kumaranwali dhok, (K 24·599).
Spirifer (Neospirifer) fasciger Keys.
Derbya sp.

Sandy greenish limestone with ironstone pebbles (=Conglomerate cap of annelid limestone of Waterfall section) near Kumaranwali dhok (K 24·596).
Spirifer (Neospirifer) fasciger, Keys. var.
Spiriferina ornata Waag. ?
Spirigerella derbyi Waag.
Dielasma sp.

Sandstones 70 ft. below Kumaranwali dhok (K 24·579).

Cladodus salinarius sp. nov.
Serpulites indicus Waag.
„ ? sp.
Lingula scrutata sp. nov.

Sandy limestones on bridle-path leading up to Kumaranwali dhok (K 24·580).

Michelinia indica Waag. and Wentz.
Derbya hemispherica Waag.
Schizodus sp.
Pleurophorus ? sp.
Neritomopsis ovulum Waag.
Bellerophon sp.
Euphemus indicus Waag.

On slopes between ruined and inhabited dhoks at Kumaranwali (K 24·581).

Amblysiphonella sp.
Arœopora ramosa Waag. and Wentz.
Productus (*Productus*) *subcostatus* Waag.
„ („) *gratiosus* Waag.
„ („) *aratus* Waag.
(*Waagenoconcha*) *purdoni* Dav.
(*Linoproductus*) *lineatus* Waag.
Chonetes (*Dienerella*) *squamulifera* Waag.
Derbya hemispherica Waag.
Streptorhynchus (*Kiangsiella*) *pectiniformis* Dav.
Enteletes pentameroides Waag.
Rhynchotetra mansuyi sp. nov.
Spirigerella derbyi Waag.
Spirifer warchensis sp. nov.
Dybowskiella grandis Waag. and Wentz.
Bellerophon blanfordianus Waag.
„ *jonesianus* De Kon.
„ *triangularis* Waag.
„ *orientalis* De Kon.
Euphemus indicus Waag.
„ *apertus* Waag.
Entalis herculea De Kon.

Macrocheilina avellanoides (De Kon).
Foordiceras transitorium Waag. *multicostata.* var. nov.

Lower Bellerophon bed on slopes above inhabited dhok, at Kumaranwali (K 24·582).

Michelinia indica Waag. and Wentz.
Productus (*Productus*) *indicus* Waag.
„ („) *subcostatus* Waag.
„ („) *gratiosus* Waag.
„ (*Waagenoconcha*) *abichi* Waag.
„ („) *abichi* Waag. *consors* var. nov.
„ („) „ *pseudopalliata* var. nov.
„ („) „ var. *serialis* Waag.
„ („) *vagans* sp. nov.
„ (*Linoproductus*) *lineatus* Waag.
„ (*Striatifera*) *compressus* Waag.
„ (*Marginifera*) *typicus* Waag.
„ („) *ovalis* Waag.
„ („) *ornatus* Waag.
„ (*Paramarginifera*) *kiangsiensis* Kays. var. *tumida* Waag.
Chonetes morahensis Waag.
Chonetella nasuta Waag.
Strophalosia plicosa Waag.
Streptorhynchus (*Kiangsiella*) *pectiniformis* Dav.
Athyris capillata Waag.
„ *subexpansa* Waag.
„ *ambiguœformis* Waag.
„ *pectinifera* Sow.
„ *simulans* sp. nov.
Spirigerella derbyi Waag.
„ „ var. *acutiplicata* Waag.
„ „ var. *roxanae* Renz.
„ *minuta* Waag.
„ *grandis* Waag.
„ *prœlonga* Waag. carinata var. nov.
Spirifer (*Neospirifer*) *fasciger* Keys. var. *nitiensis* Diener.
Hemiptychina himalayensis (Dav.)

Hemiptychina warchensis sp. nov.
Camarophoria purdoni Dav.
Derbya hemispherica Waag.
Oldhamina decipiens De Kon.
Dybowskiella grandis Waag. and Wentz.
Aviculopecten punjabensis sp. nov.
Bellerophon jonesianus De Kon.
,, *triangularis* Waag.
,, *orientalis* De Kon.
Euphemus indicus Waag.
,, *apertus* Waag.
Warthia polita Waag. ?
Bucania integra Waag.
Entalis herculea De Kon.
Macrocheilina avellanoides (De Kon).
Nautilus (*Coloceras*) *immanis* sp. nov.
Foordiceras grypoceroides sp. nov.

Productus abichi zone, Sandy limestone above Bellerophon bed along bridle-path above inhabited dhok at Kumaranwali (K 24·583).

Lonsdaleia salinaria Waag. and Wentz.
Araeopora ramosa Waag. and Wentz.
Crinoid stems.
Productus (*Productus*) *indicus* Waag.
,, (,,) *vishnu* Waag.
,, (,,) *gratiosus* Waag.
,, (*Waagenoconcha*) *abichi* Waag.
,, (,,) ,, var. *serialis* Waag.
,, (,,) ,, *consors* var. nov.
,, (,,) ,, *densipustulata* var. nov.
,, (,,) ,, *pseudopalliata* var. nov.
,, (*Striatifera*) *compressus* Waag.
,, (*Linoproductus*) *lineatus* Waag.
,, (*Marginifera*) *typicus* Waag.
,, (*Paramarginifera*) *vihianus* Diener, *salinaria* var. nov.
,, (*Paramarginifera*) *kiangsiensis* Kays. var. *tumida* Waag.

Productus (?) *asperulus* Waag.
Strophalosia indica Waag.
,, *costata* Waag.
,, *nodosa* Waag.
Chonetes (*Dienerella*) *squamulifera* Waag.
,, (,,) *grandicosta* Waag.
Chonetella nasuta Waag.
Streptorhynchus pelargonatus Schloth ?
,, (*Kiangsiella*) *pectiniformis* Dav.
Derbya grandis Waag.
Camarophoria purdoni Dav.
Rhynchonella ? *morahensis* Waag.
Terebratuloidea davidsoni Waag.
,, *depressa* Waag.
,, *crassirostris* Mansuy, *solitaria* var. nov.
Spirifer (*Neospirifer*) *fasciger* Keys. var.
,, (,,) var. *nitiensis* Diener.
,, *wynnei* Waag.
Spiriferina cristata Schloth.
Notothyris warthi Waag.
,, *inflata* Waag.
,, *subvesicularis* (Dav.) ?
Martinia elongata Waag.
,, *semiplana* Waag. *radiata* var. nov.
Hemiptychina himalayensis (Dav.).
Spirigerella derbyi Waag.
,, ,, var. *acutiplicata* Waag.
,, *prælonga* Waag.
,, ,, *carinata* var. nov.
,, *minuta* Waag.
Athyris capillata Waag.
,, *timorensis* Rothpl. *complanata.* var. nov.
,, *pectinifera* Sow.
,, *semiconcava* Waag. ?
,, *acutomarginalis* Waag.
,, *ambiguæformis* Waag.
,, *simulans* sp. nov.
Hustedia grandicosta (Dav.).
Oldhamina decipiens De Kon.
Lyttonia nobilis Waag.

Richthofenia lawrenciana De Kon.
Polypora koninckiana Waag. and Pichl.
,, *megastoma* De Kon. ?
Dybowskiella grandis Waag.
Geinitzella columnaris (Schloth).
Stenopora ovata Lonsd. ?
Synocladia virgulacea Phill.
Lucina progenitrix Waag.
Allorisma perelegans Waag.
Aviculopecten punjabensis sp. nov.
,, *nodulifer* sp. nov.
,, cf. *guadelupensis* Girty.
,, *praecox* Waag. ?
Bellerophon jonesianus De Kon.
,, *triangularis* Waag.
,, *orientalis* De Kon.
Entalis herculea De Kon.
Macrocheilina avellanoides (De Kon.).
Nautilus (*Coloceras*) *immanis* sp. nov.
,, aff. *wanneri* Haniel.

Upper Bellerophon bed, about two-thirds of the way up the slope above inhabited dhok at Kumaranwali. (K 24·601).

Productus (*Productus*) *indicus* Waag.
,, (,,) *aratus* Waag. ?
,, (*Linoproductus*) *lineatus* Waag.
,, (*Marginifera*) *typicus* Waag.
Streptorhynchus (*Kiangsiella*) *pectiniformis* Dav.
Derbya grandis Waag.
Aulosteges dalhousi Waag. ?
Enteletes sublævis Waag.
Rhynchonella (*Uncinulus*) *jabiensis* Waag. ?
Spirigerella derbyi Waag. var. *acutiplicata* Waag.
Camarophoria cf. *gigantea* Diener.
Polypora megastoma De Kon.
,, sp.
Stenopora ovata Lonsd ?
Pseudomonotis (*Prospondylus* ?) *waageni* sp. nov.
Schizodus dubiiformis Waag.
Bellerophon blanfordianus Waag.
,, *triangularis* Waag.

Upper Bellerophon bed on bridle-path to Uchali near divide above Kumaranwali dhok (K 24·597).

Productus (Productus) aratus Waag.
,, *(Waagenoconcha) purdoni* Dav.
Derbya hemispherica Waag.
,, *regularis* Waag. ?
Streptorhynchus pelargonatus Schloth ?
Orthothetes semiplanus Waag.
Athyris capillata Waag.
,, *globulina* Waag.
,, *simulans* sp. nov. var.
,, *subexpansa* Waag.
Spirigerella derbyi Waag.
,, *prælonga* Waag.
,, ,, *carinata* var. nov.
,, *minuta* Waag.
Dybowskiella grandis Waag. and Wentz
Pleurophorus imbricatus Waag.
Schizodus pinguis Waag.
Aviculopecten aff. *subfimbriatus* De Vern.
Oxytoma ? cardiiforme sp. nov.
Pseudomonotis (Eumorphotis) middlemissi Diener
Macrocheilina avellanoides (De Kon.)
Neritomopsis ovulum Waag.
Pleurotomaria durga Waag.
Entalis herculea De Kon.
Bellerophon jonesianus De Kon.
,, *impressus* Waag.
,, *triangularis* Waag.
,, *orientalis* De Kon.
Euphemus indicus Waag.
,, *apertus* Waag.
Spirorbis helix King.
Orthoceras (Protocycloceras) cyclophorum Waag
Metacoceras warchense sp. nov.
Tænioceras noetlingi Frech, *subglobosa* var. nov

Cliffs of limestone above bridle-path to Uchali north of divide (K 24·602).

Lonsdaleia sp.
Lyttonia nobilis Waag.

Spirifer fasciger Keys. var.
Fistulipora parasitica Waag. and Wentz.
Orthoceras sp.

(3) North side of valley of Jarhanwala nala.

Productus abichi beds on lower slopes above salt mines on road from Rukhla to Amb, north of spring. (K 24·603).

Araeopora ramosa Waag. and Wentz.
Productus (*Productus*) *indicus* Waag.
„ („) *gratiosus* Waag.
„ (*Waagenoconcha*) *abichi* Waag.
„ („) „ var. *serialis* Waag.
„ („) „ *consors* var. nov.
„ („) „ *pseudopalliata* var. nov.
„ (*Marginifera*) *typicus* Waag.
„ (*Paramarginifera*) *kiangsiensis* Kays. var. *tumida* Waag.
„ (?) *asperulus* Waag.
Strophalosia indica Waag.
„ *rarispina* Waag.
„ *excavata* Gein.
„ *costata* Waag ?
Orthothetes semiplanus Waag.
Streptorhynchus (*Kiangsiella*) *pectiniformis* Dav.
Chonetes (*Dienerella*) *grandicosta* Waag.
„ („) „ *biplex* var. nov.
„ („) *dichotoma* Waag.
Chonetella nasuta Waag.
Athyris capillata Waag.
„ *semiconcava* Waag.
„ *globulina* Waag.
„ *grossula* Waag.
„ *simulans* sp. nov.
„ *xetra* Diener.
„ cf. *gerardi* Diener.
Spirigerella derbyi Waag.
„ „ var. *acutiplicata* Waag.
„ „ var. *roxanae* Renz.
„ *minuta* Waag.
Dielasmina plicata Waag.

Notothyris subvesicularis (Dav.).
,, *mediterranea* Gemm. *emerita* var. nov.
Hemiptychina sparsiplicata Waag.
,, *sublaevis* Waag.
Martinia elongata Waag. *sinuata* var. nov.
Spiriferina cristata Schloth. var.
,, *multiplicata* Sow. *punjabensis* var. nov.
,, cf. *cambodgiensis* Mansuy.
Hustedia grandicosta (Dav.).
Dielasma acutangulum Waag.
Camarophoria superstes De Vern.
Rhynchonella (*Uncinulus*) *jabiensis* Waag.
Lyttonia nobilis Waag.
Oldhamina decipiens De Kon.
Richthofenia lawrenciana De Kon.
Fenestella jabiensis Waag. and Pichl. ?
Geinitzella crassa (Lonsd.).
Dybowskiella grandis Waag. and Wentz.
Hexagonella ramosa Waag. and Wentz.
Polypora sp.
Hemitrypa ? *punjabensis* sp. nov.
Aviculopecten prototextorius Waag. ?
Pleurotomaria sp.

Slopes above Salt mines near fork of road from Rukhla to Amb higher up road than K 24·603. (K 24·601).

Productus (*Productus*) *indicus* Waag.
,, (,,) *vishnu* Waag. ?
,, (*Linoproductus*) *lineatus* Waag.
,, (,,) *cora* D'Orb. ?
,, (*Striatifera*) *compressus* Waag.
,, (*Waagenoconcha*) *abichi* var. *serialis* Waag.
,, (*Marginifera*) *ovalis* Waag. ?
,, (?) *asperulus* Waag.
Scacchinella sp.
Chonetes (*Dienerella*) *dichotoma* Waag.
Chonetella nasuta Waag.
Athyris capillata Waag.
,, *subexpansa* Waag.
Spirigerella derbyi Waag.
Spirifer (*Neospirifer*) *fasciger* Keys. var.

Spiriferina multiplicata Sow.
Rhynchonella (*Uncinulus* ?) *theobaldi* Waag. (=*timorensis* Rothpl.).
Enteletes sp.
Notothyris sp.

At first fork of road from Rukhla to Amb. (K 24·605).
Productus (*Productus*) *indicus* Waag.
,, (,,) *gratiosus* Waag.
,, (*Linoproductus*) *lineatus* Waag.
,, (*Waagenoconcha*) *abichi* var. *serialis* Waag.
,, (,,) *bhalensis* Waag. ?
,, (?) *asperulus* Waag.
Chonetes (*Dienerella*) *grandicosta* Waag.
,, (,,) ,, *biplex* var. nov.
,, *strophomenoides* Waag.
Chonetella nasuta Waag.
Strophalosia indica Waag.
Athyris capillata Waag.
,, *semiconcava* Waag.
,, *globulina* Waag. ?
,, *pectinifera* Sow. ?
,, *grossula* Waag. ?
Spirigerella derbyi Waag.
,, *grandis* Waag.
Streptorhynchus (*Kiangsiella*) *pectiniformis* Dav.
Terebratuloidea davidsoni Waag.
Hemiptychina sparsiplicata Waag.
Spirifer (*Neospirifer*) *fasciger* Keys. var.
Rhynchonella (*Uncinulus* ?) *jabiensis* Waag.
,, (,, ?) *theobaldi* Waag. (=*timorensis* Rothpl.).
Synocladia virgulacea Phill.
Polypora ornata Waag. and Pichl.
Geinitzella crassa Lonsd.
Poteriocrinus sp.
Cyathocrinus sp.

Beyond first fork road from Rukhla to Amb, on left side of road. (K 24·606).
Araeopora ramosa Waag. and Wentz.

Crinoid stems.

Productus (*Productus*) *indicus* Waag.

" (") *vishnu* Waag.

" (*Striatifera*) *compressus* Waag.

" (*Linoproductus*) *lineatus* Waag.

" (*Waagenoconcha*) *abichi* Waag.

" (") " var. *serialis* Waag.

" (") " *consors*. var. nov.

" (") " *purdoni* Dav.

" (") " *fugax* sp. nov.

Productus (*Marginifera*) *typicus* Waag.

" (") *ornatus* Waag.

Chonetes (*Dictyoclostus*) *grandicosta* Waag.

" (") *deplanata* Waag.

Chonetella nasuta Waag.

Strophalosia tenuispina Waag.

" *rarispina* Waag.

Streptorhynchus (*Kiangsiella*) *pectiniformis* Dav.

Derbya altestriata Waag.

Spirifer (*Neospirifer*) *fasciger* Keys. var.

" (") .. var. *nitiensis* Diener.

" (" ?) *niger* Waag.

Athyris capillata Waag.

" *simulans* sp. nov.

Spirigerella derbyi Waag.

" " var. *acutiplicata* Waag.

" *grandis* Waag.

" *prælonga* Waag.

" *minuta* Waag.

Dielasma acutangulum Waag.

Martinia sp

Hustedia grandicosta (Dav.).

Polypora gigantea Waag. and Pichl. ?

Aviculopecten punjabensis sp. nov.

Bellerophon blanfordianus Waag.

Euphemus apertus Waag.

Pleurotomaria durga Waag.

Macrocheilina avellanoides (De Kon).

Beyond second fork on road from Rukhla to Amb near Fazalwali dhok (K 24·607).

Lonsdaleia virgalensis Waag and Wentz.
Productus (Productus) subcostatus Waag.
" (") *vishnu* Waag. ?
" (*Linoproductus*) *lineatus* Waag.
" (*Waagenoconcha*) *abichi* Waag.
" (*Buxtonia* ?) *punjabensis* sp. nov.
Chonetella nasuta Waag.
Streptorhynchus memor sp. nov.
Orthis (Schizophoria) subquadrata Fliegel.
Enteletes ferrugineus Waag. ?
Derbya hemispherica Waag. ?
Athyris capillata Waag.
" *subexpansa* Waag.
" *grossula* Waag.
Spirigerella grandis Waag.
" *derbyi* Waag.
Reticularia indica Waag.
Martinia elongata Waag. *sinuata* var. nov.
Spirifer (Neospirifer) fasciger Keys. var.
" *oldhamianus* Waag. ?
" *vercherei* De Vern.
Hemiptychina sparsiplicata Waag.
" *himalayensis* (Dav.).
" *inflata* Waag.
Lyttonia nobilis Waag.
Polypora sp.
Dybowskiella sp.
Bucania sp.

Fossils from Lower Trias (Ceratite Beds) in flaggy limestones above Upper Bellerophon bed on slopes above Kumaranwali dhok (K 24·528).

Pseudosageceras multilobatum Noetl.
Flemingites sp.
Meekoceras (Koninckites) sp.
Aspidites sp.
Ophiceras sp.

Gangamopteris bed, No. 6 (G. de P. C.).

Plant remains from the waterfall section.—Three species of *Gangamopteris* were recognised from bed No. 6, viz., *G. cyclopteroides*, Feist., *G. major* Feist., and *G. kashmirensis* Seward ; one species of *Glossopteris*, *G. indica*, and one specimen of *Annularia*. There are also several specimens of branchlets, probably Equisetaceous. The *Gangamopteris* beds of Kashmir are placed in the base of the Permian by C. S. Middlemiss and by C. Diener ; their position in the Salt Range sequence appears therefore to correspond exactly with their age in Kashmir.[1]

[1] See *Pal. Indica*, New Ser , vol. V, pt. 2, p. 111, and vol. XII, p. 6.

EXPLANATION OF PLATES.

PLATE 10. FIG. 1.—Waterfall in Productus Limestone, Jarhanwala Nala.
FIG. 2.—Talchir Boulders adherent to Purple Sandstone, Jansukh Nala.

PLATE 11. FIG. 1.—Oil Shales in Jarhanwala Nala.
FIG. 2.—Junction of the Speckled and Purple Sandstones, Jarhanwala Nala.

PLATE 12.—Panoramic view of the valley of Jarhanwala Nala above the waterfall.

PLATE 13.—Geological map of portion of the Salt Range, Shahpur, Punjab. Scale 3 inches—1 mile.

THE NAOKI (HYDERABAD) METEORIC SHOWER OF THE 29TH SEPTEMBER, 1928. BY A. L. COULSON, M.SC. (MELB.), D.I.C. (LOND.), F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 14 to 20.)

INTRODUCTION.

Mention of the Naoki fall has already been made in the General Report of the Geological Survey of India for 1928.[1] The shower fell at about 5 P.M. on the afternoon of the 29th September, 1928, at and near the village of Naoki (19° 14′ 30″; 77° 0′ 0″) in the Parbhani district of H. E. H. the Nizam's Dominions. Naoki is some four and a half miles N. N. W. of Purna railway-station on the Hyderabad-Godavari railway.

Locality.

Four stones are definitely known to have fallen in this shower, two near Naoki and one near each of the villages of Korgaon (19° 13′ 0″; 76° 59′ 0″) and Mategaon (19° 13′ 30″; 77° 0′ 30″) which lie one and three-quarters and one and a quarter miles respectively to the S. S. W. and S. S. E. of Naoki. The relative positions of these villages are shown in the accompanying sketch-map of the vicinity of Purna (Figure 1).

Number of stones.

Both the stones which fell at Naoki have been received by this Department, one having been presented by Mr. G. H. H. Mills, Criminal Investigation Department of H. E. H. the Nizam's Government, and the second through the agency of Mr. Mills by Mr. Abdulla of Nander. They have been registered as "Stone No. 294" in the meteorite collections of the Geological Survey of India. But for the interest shown by Mr. Mills, this important fall would probably have passed unnoticed as doubtless happens in the case of numerous meteoric falls.

Two stones recovered from Naoki.

The first stone weighed 4,920·7 grammes when received by the Geological Survey of India on the 28th November, 1928; the second stone 1,762·55 grammes when received on the 22nd January, 1929, the total weight of stone

Total weight.

[1] *Rec. Geol. Surv. Ind.*, LXII, 1929, pt. 1, pp. 15-16.

thus recovered being 6,683·25 grammes. Both stones were exhibited at the Annual Meeting of the Asiatic Society of Bengal held at Calcutta on February 4th, 1929.

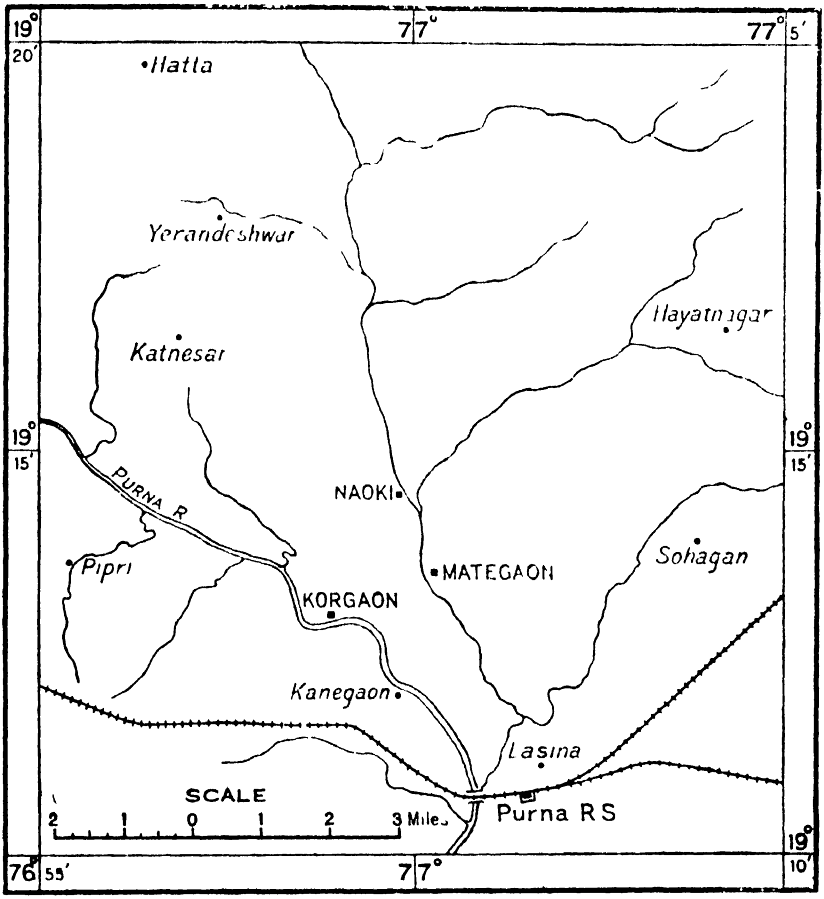

FIG. 1. -Sketch-map showing the positions of Naoki, Korgaon and Mategaon.

Circumstances of the fall.

Circumstances of the fall are given in the following extracts from the correspondence with Mr. Mills. In a letter dated Hyderabad, the 28th October, 1928, Mr. Mills wrote :—

"The Superintendent of Police, Parbhani District in H. E. H. the Nizam's Dominions, reported to me the other day that at Mozai Saoki[1] Station House, Purna,

[1] Actually Naoki.

a number of stones (? meteorites) recently fell from the sky in the night-time during a storm of rain. One of these stones, which is about 6×6×4 inches in size, has been sent to me. The surface of the stone is of blackish colour as though it has been burnt, and the section is of slaty grey colour and of rough texture. The stone is, I need hardly say, very heavy."

Mr. Mills was requested kindly to forward the stone to this Department and to ascertain full particulars of the circumstances of the fall. In his reply he stated that he had obtained a further report on the circumstances of the fall. He added that most of the meteorites had been taken away as mementos by various local officials but that he was trying to recover one or two more for this Department.

In a further letter dated Purna, the 26th November, 1928, Mr. Mills gave the following information regarding the fall of meteorites at the villages of Naoki, Malegaon [1] and Kawargaon [2]:—

"The four meteorites were discovered at the distances apart as shown in the chart below. As it was raining heavily at that time there were only a few people in the fields. The evidence of three persons has been recorded who state that they heard a noise from the sky and on looking in the direction from which it came saw a splashing of mud and heard a sound accompanying it. They could not say whether it was a sound as of something hot falling into water. There were no luminous phenomena. Through fear, no one went near the place where the meteorites had fallen for two days, so it is impossible to say whether they were hot when they fell. The occurrence took place approximately at 5 P.M. on the 29th of September 1928. The maximum distance to which the stones penetrated into the ground was 18 inches."

A copy of Mr. Mills' chart is reproduced below as figure 2. The distances between stones Nos. 1 and 2, 2 and 3 and 3 and 4 are thus 1,849, 981 and 747 yards, respectively, taking one pace equivalent to 33 inches.

In a letter dated the 3rd January, 1929, Mr. Mills advised the despatch of another of the meteorites which fell at the village of Naoki. He stated that he had obtained it through one of his officers from an Arab named Abdulla of Nander to whom it had been given. A translation of the Urdu inscription found on a label on this stone when received by the Geological Survey of India, read as follows: Weight 4 seers 14 chhataks. Colour—black. Side—broken. Received (signed) Said Ali, Zamindar.

[1] Actually Mategaon.
[2] Actually Korgaon.

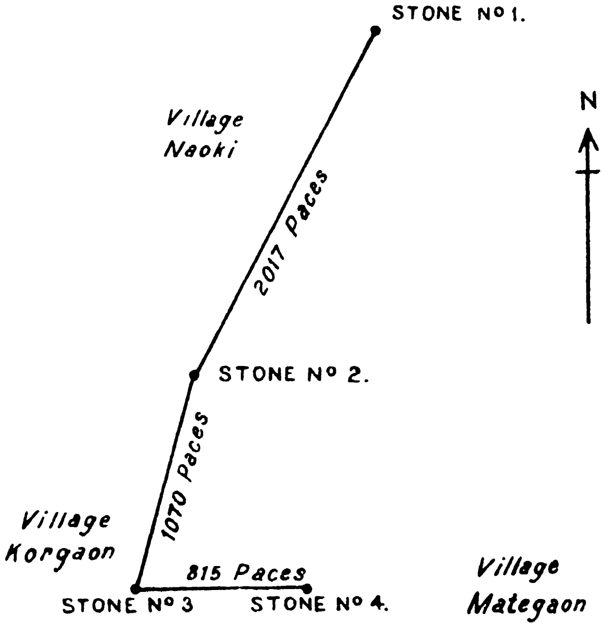

FIG. 2.—Chart showing where the four stones of the Naoki meteoric shower fell.

It will be noted that the stones presented to the Geological Survey of India are Nos. 1 and 2 of the above chart. No information concerning the weight of Nos. 3 and 4 has been received.

GENERAL DESCRIPTION OF THE STONES.

Large stone (294A).

The first stone, weighing 4,920·7 grammes, is an almost complete specimen, probably less than 200 grammes weight having been lost from the impact with the earth or by subsequent human agency. It is roughly rectangular in shape; its greatest length is 7·2 inches, greatest breadth 5·5 inches, and greatest thickness 4·0 inches. The dimensions of the fractured surface shown in Plate 14, figure 1, and Plate 16, figure 1, are roughly 4·2 by 2·5 inches. Plate I depicts what may be termed the front and back faces of the stone, Plate 15 the sides, and Plate 16 the top and bottom.

The crust possesses the usual greyish black colour and is very thin, being less than 0·5 mm. thick; no definite flow lines can be seen. Numerous hollows can be observed in the plates mentioned

above; they are generally shallow if small and more basin-shaped if large. Many of the larger depressions are compound in nature. One small rectangular depression, forming part of a larger hollow, is shown in Plate 15, figure 1; it is relatively deep and very narrow in comparison with its length.

Small stone from Naoki.

The smaller stone weighed 1,762·55 grammes when received. A large proportion of it had been broken off, chiefly, it is presumed, by human agency. Two "secondary crusts," however, can be seen on its surface; these were formed in the last stages of the stone's journey towards the earth, thus indicating that subsequent to the main disruption of the parent meteorite of the shower into at least four stones, the stone in question had also been disrupted just previous to reaching the earth's surface. These are shown (S and S^1) in figure 1, and indistinctly (S) in figure 2 of Plate 17. Approximately parallel lines of flow can be made out in these secondary crusts. The main crust is black and thin; it shows no definite lines of flow but there are numerous shallow depressions which can be well seen in Plates 17, 18 and 19. The maximum length of the stone was approximately 6 inches,[1] much of its length having been lost through fracture; its greatest thickness was 3·8 inches.

Specific gravity.

The smaller stone had a specific gravity of 3·701; this is higher than the usual specific gravity of stone meteorites[2] and is doubtless to be ascribed to the relative abundance of nickel-iron which this specimen contains (*vide* p. 449).

Small stone broken for distribution and study.

For the purposes of exchange and study, this stone was broken into the following pieces: 294B, 1,282·01 grammes; 294 C, 234·37 grammes — presented to the British Museum; 294 D, 247·54 grammes — presented to the National Museum of Natural History, Paris.

Classification.

The structure and colour of the Naoki meteorites as displayed in the hand specimens and in three thin sections of the smaller stone, show them to be chondrites. Their classification, according to Brezina,[3] is No. 21—

[1] The stone has since been broken and its length is now much less.
[2] O. C. Farrington. "Meteorites." Chicago, 1915, p. 217.
[3] A. Brezina. "The Arrangement of Collections of Meteorites." *Proc. Amer. Phil. Soc.*, XLIII, 1904, p. 236.

grey chondrite, Cg. They possess a firm, grey mass with chondrules of various kinds breaking with the matrix.

Three slides, Nos. 19382, 19383 and 19384 in the collections of the Geological Survey of India, were made from small fragments obtained in the breaking-up of the smaller stone. These show that nickel-iron, showing the usual bluish reflection in reflected light, is in excess relative to the amount usually found in stone meteorites (*see* Plate 20, figures 3 and 4). It occurs generally as isolated grains or variously-shaped flakes filling the spaces between the silicates. A few of the isolated grains are rounded and to a certain extent resemble chondri.

Composition—nickel-iron.

In slide No. 19384, which shows two sections across the crust, thin, anastomosing, black veins can be seen branching out from the crust. It would appear that these veins consist essentially of the same material as the substance of the stone and that they have been produced by the penetration of heat into the fissures of the meteorite during its passage through the atmosphere.[1] These veins are absent from the other thin sections which were made from material remote from the crust. It is interesting to note that unaltered, irregular grains of nickel-iron occur in the midst of the fused, black, crustal area, indicating that the heat developed during the passage of the stone through the atmosphere was insufficient to fuse the nickel-iron. Partially fused crystals of olivine can also be seen in the crustal zone.

Veins.

Besides nickel-iron, troilite is very abundant but not to such an extent. In the crustal zone, it has fused and forms an indistinguishable part of the black crust. This is only to be expected as troilite is the most fusible ingredient of meteorites. Away from the crust, troilite is seen as distinct grains, at times, however, intergrown with nickel-iron; its bronze-yellow colour serves to distinguish it from the bluish nickel-iron.

Troilite (pyrrhotite).

The most abundant silicate is olivine; and next in abundance to it is enstatite. True monosomatic chondri of olivine are rare but polysomatic chondri of this mineral, and of enstatite, are common. An excellent

Olivine.

[1] See also Farrington, *op. cit.*, p. 88.

eccentric, radiating chondrus of olivine, with brown glass interstitial between the constituent lamellæ, may be seen in Plate 20, figure 1; another of a different type is shown in figure 2 of the same plate. The textural and structural relations of these two chondri are shown in figures 3 and 4 (Plate 20). Granular chondri of olivine are common throughout the sections.

Enstatite.

Enstatite is abundant in all sections. It shows a frequent fibrous structure, prismatic cleavage, pinacoidal parting, straight extinction, low interference colours and prismatic habit. It is abundantly intergrown with olivine in chondri and frequently forms the ground-mass in which hypidiomorphic crystals of olivine are set. Eccentrically rayed chondri of enstatite occur, the fibres of these being thinner and closer together than the lamellæ of somewhat similar olivine chondri.

Glass.

Glass is, of course, present in the Naoki stones. It is variously distributed throughout in chondri, enclosed in individual crystals of minerals, between lamellæ of olivine and to a lesser extent between the fibres of enstatite.

EXPLANATION OF PLATES.

PLATE 14. FIG. 1.—Naoki Meteorite, 294 A, front view.
FIG. 2.—Naoki Meteorite, 294 A, back view.

PLATE 15. FIG. 1.—Naoki Meteorite, 294 A, side view.
FIG. 2.—Naoki Meteorite, 294 A, opposite side to that shown in figure 1.

PLATE 16. FIG. 1.—Naoki Meteorite, 294 A, end view showing fractured surface.
FIG. 2.—Naoki Meteorite, 294 A, end view, opposite to that shown in figure 1.

PLATE 17. FIG. 1.—Naoki Meteorite, 294 B, as received, showing the crust and fractured surface on which two secondary crusts, S and S[1], are developed.
FIG. 2.—Naoki Meteorite, 294 B, showing fractured surface, crust and secondary crust, S; this view was obtained by rolling the stone towards the observer from the position of figure 1.

PLATE 18. FIG. 1.—Naoki Meteorite, 294 B, side view; this is the reverse side of the stone which appeared when the specimen was revolved from left to right around a vertical axis from the position shown in figure 1 of Plate 17.
FIG. 2.—Naoki Meteorite, 294 B, side view, showing the surface seen when the top of the stone, as shown in figure 1, was rotated on a horizontal axis towards the observer. The crustal area, A, can be seen in both figures.

PLATE 19. FIG. 1.—Naoki Meteorite, 294 B, end and fore-shortened side view.

FIG. 2.—Naoki Meteorite, 294 B, showing the crustal area seen when the stone was rotated for 45° about a vertical axis from left to right (towards the observer) from the position shown in figure 1.

PLATE 20. FIG. 1.—Photomicrograph of the smaller Naoki meteorite, showing an eccentric, radiating chondrus of olivine; the spaces between the lamellæ are occupied by brown glass. (× 140).

FIG. 2.—Photomicrograph of the smaller Naoki meteorite, showing a chondrus of olivine with brown glass interstitial between the lamellæ of olivine. (× 140).

FIG. 3.—Photomicrograph of the smaller Naoki meteorite, showing the chondrus of figure 1 and its textural and structural relations. (× 31).

FIG. 4.—Photomicrograph of the smaller Naoki meteorite, showing the chondrus of figure 2 and its textural and structural relations. (× 31).

MISCELLANEOUS NOTES.

Note on a boring for water at Daryapur.

In the year 1914 Dr. C. S. Fox examined the water supply of the saline tract in Berar, and made certain recommendations for its improvement. Among these was a suggestion for a boring which " must be treated in the spirit of experiment, and, as such, a hazardous one, with the odds much against success ." The boring was " to go through the alluvium, and, if no fresh artesian water is obtained, to be continued into the underlying Trap for at least 100 feet."

Accordingly, a boring was commenced at Daryapur in 1926, and was finally stopped in 1928 when the drill had reached a depth of 1,373 feet. No appreciable supply of water was obtained.

The " saline tract " is a flat alluvial plain lying on both sides of the Purna river. The results of borings in different parts of such an area would be very similar. Those obtained at Daryapur near the centre of this tract should, therefore, be typical of the whole region.

I visited the drillings on two occasions, and made a detailed examination of the core to a depth of 1,282 feet (see detailed description). The uppermost 320 feet was composed of alluvium, and the remainder of rocks belonging to the Deccan Trap series.

The most striking features of the alluvium were: its shallowness, its clayey nature, and the absence of sandy or gravelly beds. These characteristics are all unfavourable to the existence in it of large quantities of water ; consequently I do not think that deep wells or borings in the " saline tract " have much chance of success.

The Deccan Trap rocks include 13 distinct basalt flows, and seven ash beds. The flows are of the normal Deccan Trap type, and vary only slightly in size of grain and habit. Each one is separated from its neighbours by a porous inter-trappean zone, and sometimes by an ash bed also. Were it not for these zones, it would often be impossible to separate one flow from another. The flows average 70·5 feet in thickness, with a maximum of 146 feet, and a minimum of 12 feet.

The ash beds occur between the flows at intervals from 716 to 1,153 feet below ground level. They consist of fine grained shaly rocks containing a few irregular glassy fragments. Sometimes they are red, sometimes black like carbonaceous shale, and in one case creamy white. Their average, maximum, and minimum thicknesses are 4·1 feet, 12 feet, and 1 foot, respectively.

It is impossible to make any accurate estimate of the probable depth of the Trap in this area based on the evidence gained from the examination of the core. The only clue to this is given by the presence of ash beds. These rocks are common in the upper 5,000 feet of the Deccan Trap series, but have not so far been found within 500 feet of its base. It is clear, therefore, that, unless this area is an exception, there is no prospect whatever of passing through the basalt into the underlying rocks for another 300 feet. Judging

by the great thickness of the basalt exposed in the adjacent Chikalda scarp, it is probable that there is still 1,000 feet or more of that rock below the level reached by the present boring.

Detailed Description of Boring Core.

Depth.			Rocks encountered.
	0 to 290	feet.	Alluvial clays.
	290 to 320	"	Nodular calcareous clays.
Flow 1	320 to 350	"	Decayed basalt.
	350 to 390	"	Very fine-grained black basalt.
	390 to 466	"	Black basalt.
Flow 2	466 to 481	"	Porous zeolitic basalt.
	481 to 572	"	Rather coarse-grained basalt.
Flow 3	572 to 630	"	Porous zeolitic basalt.
	630 to 667	"	Grey basalt.
Flow 4	668 to 683	"	Mainly porous zeolitic basalt.
	683 to 694	"	Fine-grained grey basalt.
	694 to 716	"	Mainly porous zeolitic basalt.
Inter-trappean 1	716 to 720	"	A black laminated clay composed of rounded palagonite grains. Probably a volcanic ash.
Flow 5	720 to 740	"	Amygdaloidal basalt.
	740 to 857	"	Coarse-grained black slightly porphyritic basalt.
Inter-trappean 2	857 to 869	"	Ash. Similar to 716-720.
Flow 6	869 to 905	"	Porous somewhat porphyritic zeolitic basalt.
	905 to 906	"	Very porous glassy basalt. Possibly some ash.
Flow 7	906 to 946	"	Slightly porphyritic reddish brown basalt.
	946 to 989	"	Somewhat coarse-grained porphyritic black basalt.
Inter trappean 3	990 to 995	"	Ash. Similar to 716-720 but coarser.
Flow 8	995 to 1,010	"	Nodular black basalt.
	1,010 to 1,015	"	Reddish brown lamellar basalt.
Inter-trappean 4	1,015 to 1,018	"	Dark brown ash.
Flow 9	1,018 to 1,096	"	Rather coarse-grained grey trap. Sometimes nodular.
Inter-trappean 5	1,096 to 1,098	"	White ash.
Flow 10	1,098 to 1,110	"	Porous earthy red basalt.
Inter-trappean 6	1,110 to 1,112	"	Reddish tuff.
Flow 11	1,112 to 1,145	"	Coarse grey basalt with a few palagonite nodules.
	1,145 to 1,152	"	Highly porous zeolitic basalt.
Inter-trappean 7	1,152 to 1,153	"	Green tuff.
Flow 12	1,153 to 1,220	"	Coarse grey basalt.
	1,220 to 1,228	"	Porous earthy basalt.
Flow 13	1,228 to 1,282	"	Coarse-grained black basalt.

H. CROOKSHANK.

Note on the alleged occurrence of fossil eggs at Yenangyaung, Upper Burma.

In the General Report of the Geological Survey of India for 1925,[1] reference is made to a " fossil egg " discovered in the Red Bed at the north end of the Yenangyaung Oil Field, by Dr. N. L. Sheldon. The shell of this object was badly broken but its reconstruction on a plasticine mould showed it to be about 2½ inches long by 1¼ inches broad and ½ inch thick, and flattened longitudinally. Comparison of this reconstruction with eggs of crocodiles, lizards, tortoises and birds led to its tentative identification by Mr. Tipper as reptilian, but this observer noted several differences in shape and structure between it and any recent reptilian genus. Such differences were thought to be due, possibly, to changes during fossilisation.

In April, 1927, when visiting the site of this discovery a complete specimen similar to Mr. Tipper's reconstruction was discovered by the writer, and a subsequent detailed examination of this locality led to the discovery of four whole specimens and fragments of many broken ones. Of these, two whole specimens and fragments of several broken ones had every appearance of occurring *in situ*, being firmly embedded in sandy clay in steep cliff-like exposures. All these specimens conform to a remarkable degree to the contour attributed by Mr. Tipper to the fragments he examined, the length being slightly greater than twice the breadth and three times the thickness. The profusion of these objects and their fragile nature caused their fossil origin to be called in question, more particularly as they occurred in strata in which much more robust crocodilian and tortoise remains had suffered extreme comminution. It was not, however, until a complete specimen, broken during extraction, was found to contain the pupa of an insect, that their true nature was discovered. This pupa was tentatively identified by Dr. J. Coggin Brown as that of a longicorn beetle. By the courtesy of Doctors Parker and Blair of the Natural History Museum, South Kensington, I was able, while on leave in 1928, to confirm this identification, when it was also found that certain genera of the family Cerambycidæ pupate in a calcareous cocoon which is stated by Stebbing to be peculiar to the genus Plocæderus. In an account of the life history of this insect Stebbing states :—

" The beetles appear on the wing in March, and soon after pair and lay eggs in the bark of either sickly or freshly felled trees. From these eggs small grubs hatch out in April and feed for a time in the bast layer, making winding galleries in the bark and sapwood. As the larvæ increase in size and their mandibles become stouter, they bore down deeper into the sapwood, and spend the time until nearly full-grown, eating out deep, winding galleries, which remove all the bast below the outer bark and groove deeply into the sapwood. When nearly full-grown, they tunnel down into the heartwood and eat out a pupal chamber in this, which is more or less at right angles to the long axis of the tree. About August-September the larva is full fed, and changes into the pupal state within the curious calcareous cocoon peculiar to this insect."

Stebbing also states that this insect attacks the following trees :—

" Sal (*Shorea robusta*), Dehra Dun; *Odina wodier* (Jhingham), Dehra Dun; *Bombax heptaphyllum*, United Provinces Terai; *Butea frondosa* (Dhak), United

[1] *Rec. Geol. Surv. Ind.*, Vol. LIX, pp. 14—15.

Provinces Terai; *Bombax malabaricum* (semul), United Provinces; *Spondias mangifera*, Tista Valley, Eastern Himalaya (900 ft.), Thapal, Saharanpur District; Mango (*Mangifera indica*), Chicacole, Ganjam, Madras."

None of the species mentioned occur at Yenangyaung where in fact timber is entirely absent, and in the immediate neighbourhood of the discovery the vegetation consists almost entirely of Tazaungpyathat (*Euphorbia antiquorum* Linn.) and Kanako (*Jatropha gossypifolia* Linn.).

In the course of field work at Yenangyaung in August, 1929, I came across several more specimens of the cocoon just above the Red Bed near the source of the Yedwinaing Yo. These specimens were firmly embedded in soft sandy clay in a very steep exposure, but close examination revealed them to be inside partially decayed vegetation which when traced laterally proved to be the root of a shrub of the species *Jatropha gossypifolia*. Later, near this locality another specimen was found partially enclosed by the decaying root of the *Euphorbia* (*antiquorum*) which is conspicuous in the flora of the area. It is evident that the larva bores out a passage along the roots of these shrubs, probably from the stem, and secretes its calcareous cocoon at the end of the larval tunnel so formed. The subsequent decay of the root in which it has been secreted leaves the calcareous cocoon embedded in the rocks on which the shrub was growing and readily accounts for their occurrence apparently *in situ* in these rocks.

A curious feature of the occurrence of these cocoons in the neighbourhood of Yenangyaung is their profusion in the immediate neighbourhood of the Red Bed which characterises the Pegu-Irrawaddian boundary. The species of *Euphorbia* and *Jatropha* in which they occur are widely distributed throughout this area but I have found at least ten cocoons in and near the Red Bed for every one found at other horizons. It appears that some feature of this bed, possibly its colour or some mineral constituent of it, has some special attraction for this insect.

A brief reference to this subject appeared in the General Report of the Geological Survey of India for the year 1928,[1] in which it is stated that the recent finds of this object had been identified as the pupating cases of modern beetles, but this note has been prepared as a result of more recent observations shewing how the cocoons become buried to a considerable depth in undisturbed strata, giving them the appearance of being *in situ*.

C. T. BARBER.

Stebbing, E. P. "Indian Forest Insects", pp. 296—297. *Op. cit.*, pp. 295—296.
[1] *Rec. Geol. Surv. Ind.*, Vol. LXII ,Part I, p. 26.

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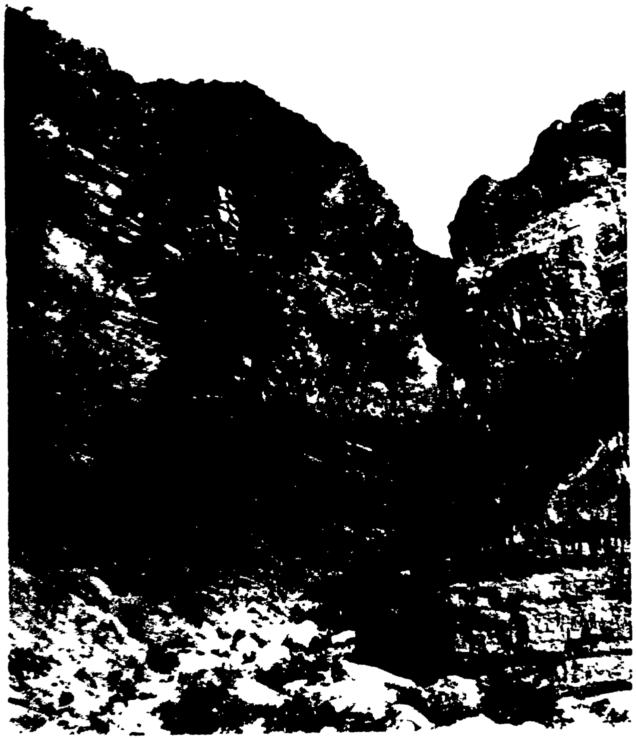


G. de P. Cotter, Photo

FIG 1 WATERFALL IN PRODUCTUS LIMESTONE, JARHANWALA NALA

G. S. I. Cal. atti

FIG 2 TALCHIR BOULDERS ADHERENT TO PURPLE SANDSTONE, JANSUKH NALA

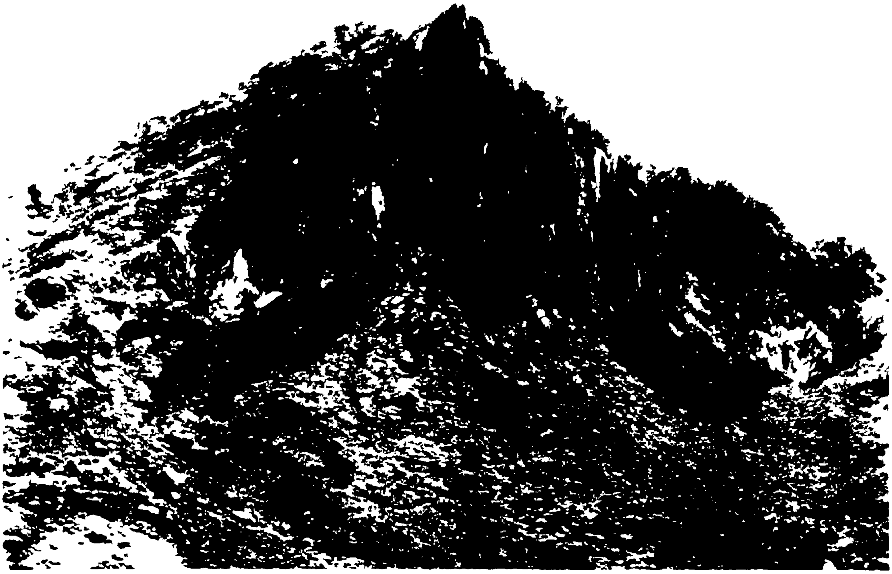


FIG 1 OIL SHALES IN JARHANWALA NALA

G de P Cotter, Photo *G S I Calcutta*

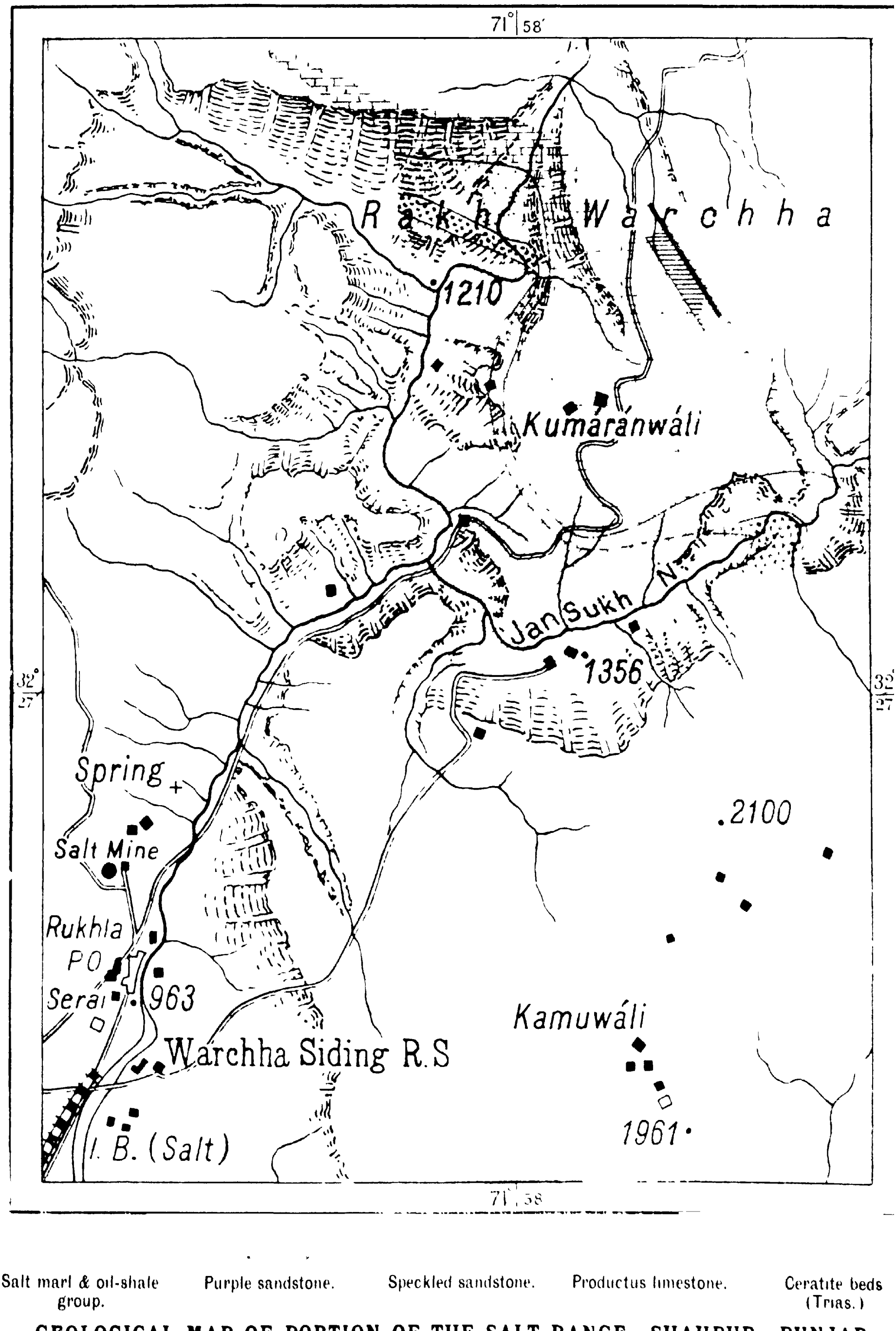
FIG 2 JUNCTION OF THE SPECKLED AND PURPLE SANDSTONES JARHANWALA NALA

The cooly has one hand resting on a Talchir boulder

G de P Cotter, Photo

G. S. I. Calcutta.

PANORAMIC VIEW OF THE VALLEY OF JARHANWALA NALA ABOVE THE WATERFALL



GEOLOGICAL MAP OF PORTION OF THE SALT RANGE, SHAHPUR, PUNJAB.

GEOLOGICAL SURVEY OF INDIA.

Records, Vol. LXII, Pl. 14.

Fig. 1. Front view.

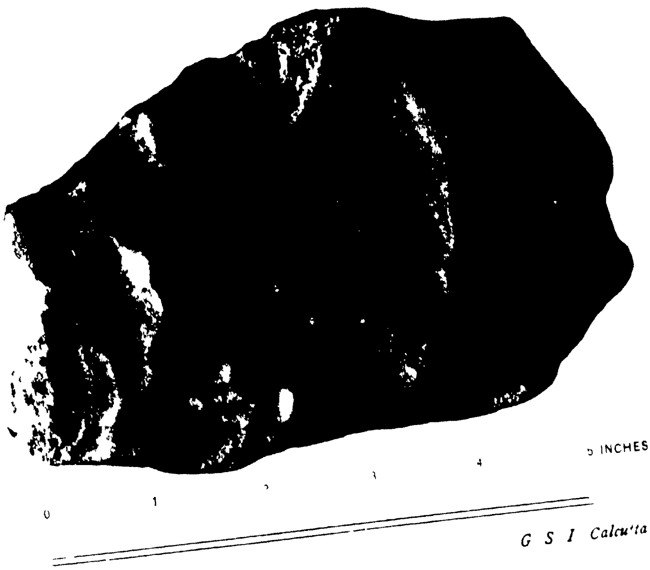
T. C. Choudhury, Photos.

G. S. I. Calcutta.

Fig. 2. Rear view.

THE LARGER NAOKI METEORITE, 294 B.

Fig 1 Side view



G S I Calcutta

T C. Choudhury, Photos

Fig 2 View of opposite side

THE LARGER NAOKI METEORITE 294 A

Fig. 1 End view, showing fractured surface

0 1 2 3 4 5 INCHES

T. C. Chowdhury, Photos. *G. S. I. Calcutta.*

Fig. 2. View of opposite end.

THE LARGER NAOKI METEORITE, 294 A.

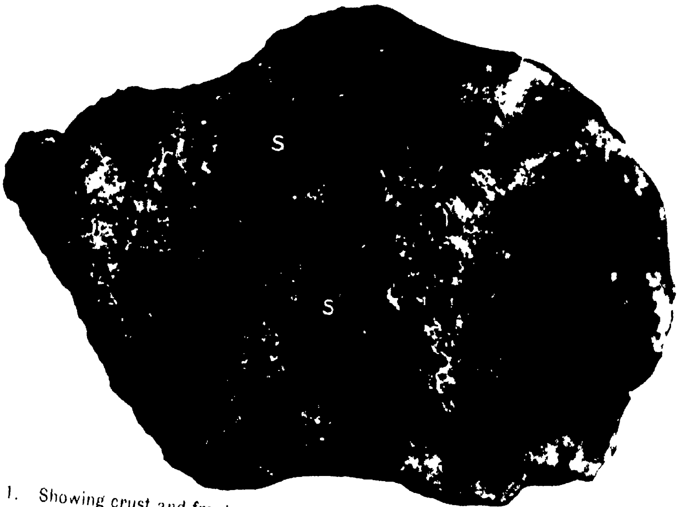


Fig. 1. Showing crust and fractured surface on which two secondary crusts, S. and S', are developed.

0 1 2 3 4 5 INCHES

Drawing Office, Photos. *G. S. I. Calcutta.*

Fig. 2. Showing fractured surface, crust, and secondary crust S of Figure 1.

THE SMALLER NAOKI METEORITE, 294 B.

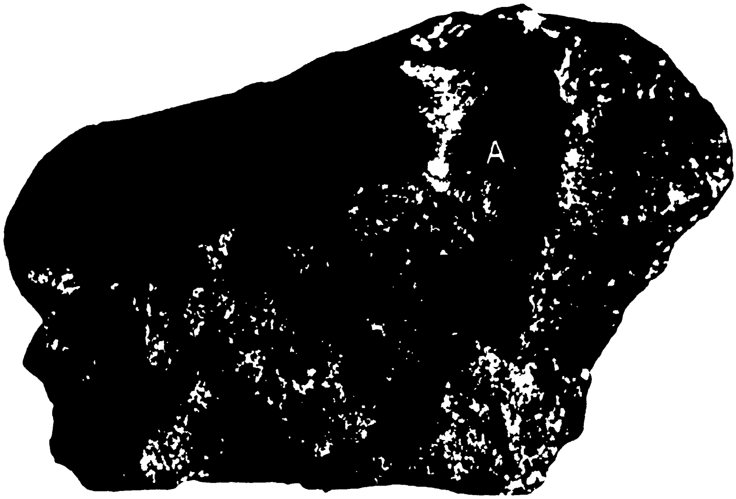


Fig 1 Side view.

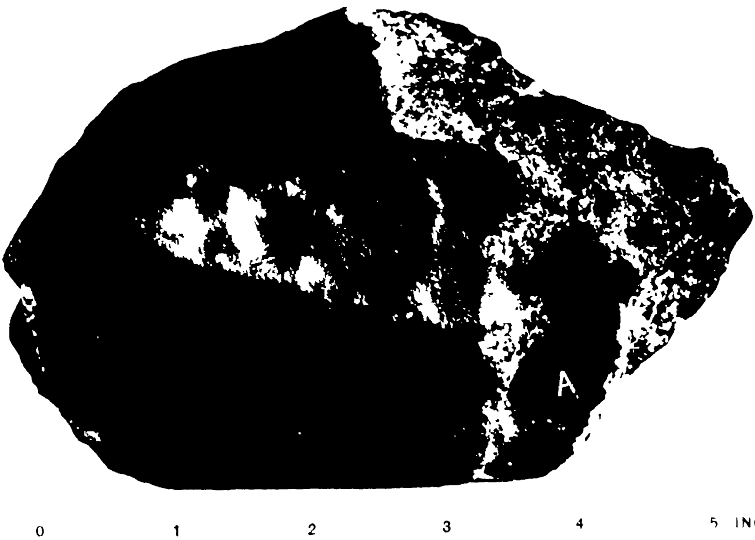


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Fig. 2. Side view, showing same crustal area, A, as in figure 1

THE SMALLER NAOKI METEORITE, 294 B.

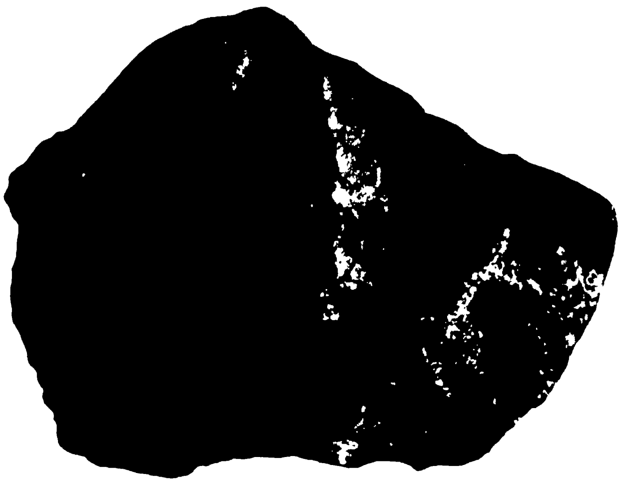
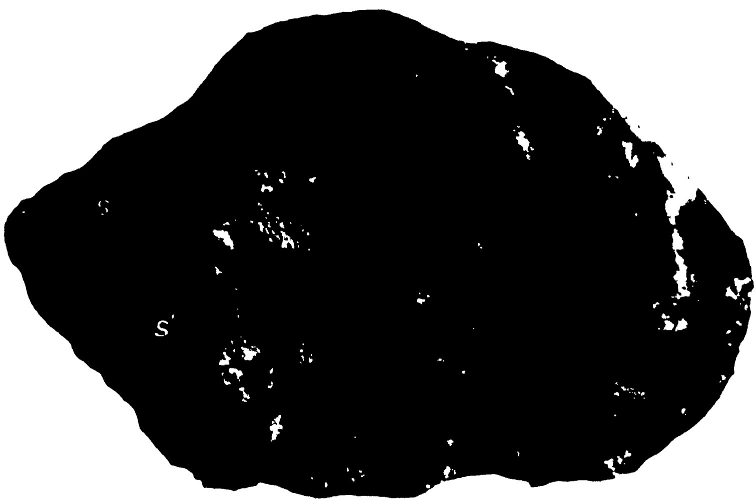


Fig. 1. End and side view.



0 1 2 3 4 5 INCHES

Drawing Office, Photos — *G. S. I. Calcutta*

Fig. 2. Crustal area seen when the stone was rotated for 45° about a vertical axis from left to right (towards the observer) from the position shown in Figure 1.

THE SMALLER NAOKI METEORITE, 294 B.

Fig 1 Eccentric, radiating chondrus of olivine (X 128)

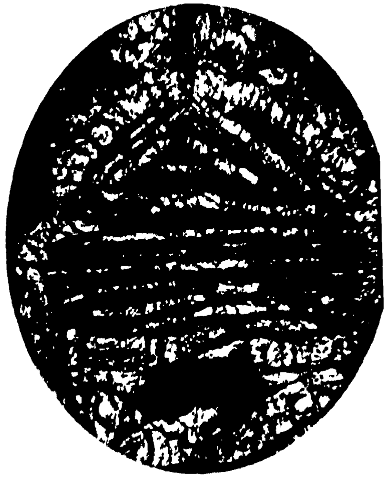


Fig 2 Eccentric chondrus of olivine (X 128).

Drawing Office, Photos. *G S I. Calcutta.*

Fig 3 This shows the relations of the chondrus shown in Fig 1 (X 28)

Fig 4 This shows the relations of the chondrus shown in Fig 2 (X 28)

SECTIONS OF THE SMALLER NAOKI METEORITE, 294 B